A COMPARISON OF VARIABLE SELECTION CRITERIA FOR MULTIPLE LINEAR REGRESSION: A THIRD SIMULATION STUDY

THESIS

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THESIS

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Table of Contents

List of Figures

List of Tables

Abstract

The goal of this thesis research is to introduce and study a modification of Miller's Method which we call the Modified-Miller's method (MM method), study two step subset selection procedures, these of which apply Miller's Method in the first step and employs another method (Minimum MSE or Minimum Sp or Minimum Cp) in the second step and these of which employ another method (Minimum MSE or Minimum Sp or Minimum Cp) in the first step and applies Miller's Method in the second step. The results of all techniques will be compared including the results of the previous simulation studies done by Hanson in 1988 and by Woollard in 1993. In the researches mentioned above, Minimum MSE, Minimum Sp, Minimum Cp and Miller's method were studied.

Each of the techniques, studied in this thesis effort was applied on generated data with known multicollinearities, random predictors, variances, sample sizes and error terms.

The performance of each method is evaluated by employing two performance measurements. The first one, denoted PM (Performance Measurement), calculates the percentage of correct variables in a model. The second one, denoted FM

(Full Model) calculates the ratio of perfect models, the set of which is {X1 X2 X3} for this research, to the number of all models.

The Response Surface Methodology technique was employed to set up a 2^6 full factorial experiment in order to study the effectiveness of each subset selection method with respect to the known data characteristics.

Including the results of Hansen's and Woollard's study, eleven different subset selection techniques were compared. Considering the PM and FM measurements together, the CpMLR (method which is a two stage subset selection method) performs the best, and with a very small difference the SpMLR method (which is another two stage subset selection procedure) is close behind the CpMLR. The Modified-Miller's Method, (which is a one step subset selection method) performs the third best.

A COMPARISON OF VARIABLE SELECTION CRITERIA FOR MULTIPLE LINEAR REGRESSION: A THIRD SIMULATION STUDY

I. Introduction

Background

Regression analysis is a statistical methodology that is used to relate variables. The variable of interest, which is called the dependent or response variable is related to one or more predictor or in other words independent variables. In the literature the dependent variable is mostly denoted by Y, and the independent variables are denoted by X1, X2...Xp. The objective in regression analysis is to build a regression model (equation). This model is used to describe, predict and control the dependent variable on the basis of independent variables (Bowerman and O'Connell, 1990:3).

In real world applications, many times an analyst is involved in regression analysis, where the number of independent variables is over 100. The cost of maintaining

a model with large number of independent variables is high, and it is hard to understand and gain insight into the studied phenomena. Because of the large variance the predictive capability of such a model is also small. In order to minimize these problems, the analyst needs to find the correct number of independent variables to include in the regression model. The concern of subset selection in multiple regression is to find the best solution to this requirement. It is not an easy task. The topic of subset selection is one which is viewed by many statisticians as "unclean" or "distasteful" (Miller, 1990:ix).

Subset selection procedures mentioned in the literature can be classified as (1) considering all-possible subsets, and, (2) finding the sub-optimal models. All-possible subsets methods are called guaranteed methods, but because of the large computational requirement often they are hard to implement. For a set of 25 independent variables 33,554,431 possible models need to be examined. The guarantee of these methods is to find the best model for the pool of variables already available. But what if the pool doesn't include all significant variables? Also the final best set of variables obtained for a sampled data might be different from the best set of variables obtained for another sampled data. On the other hand, the sub-optimal methods (the most widely used ones are the stepwise

procedures) don't consider all-possible models, therefor they need less computational effort. They are based on finding and including in the model the most significant variable given that the previously selected variables are in the model. These methods do not even guarantee that the final model is the best one for the given pool of variables.

The need for better subset selection methods is one of the things that is addressed this thesis research.

Problem Statement

The objectives of this thesis effort are: (1) introduce and implement two stage subset selection procedures, (2) make an improvement in Miller's method, and, (3) make an extension of Ross Hansen's 1988 and David Woollard's 1993 thesis research by comparing the results of the methods they have examined (Minimum MSE, Minimum Sp, Minimum Cp and Miller's Method) with the results of the methods implemented in this research.

Assumptions

It is assumed that: the data generated and used through the research is a random sample from the

predetermined population, the error terms are identically and independently distributed (iid) and come from normal populations with mean zero and variance σ^2.

Scope

This study is an extension of Ross Hansen's 1988 and David Woollard's 1993 research. In this thesis effort six different two stage subset selection procedures were examined. In the first three, Miller's Method was used for screening, and in the second three Miller's Method was used for final model selection. Improvements were done in Miller's Method and the obtained method was called Modified-Miller's Method. All the results of the employed methods in this thesis research are compared including the results of methods studied by Hansen and Woollard.

II. CONCEPT OVERVIEW

Least Square Regression

In the subset selection criterias employed in this thesis research, Least Square technique is widely used. In this chapter properties and the concept of this technique are given. In general, the linear least squares regression equation is written:

$$y = \beta_0+\beta_1 x_1+\beta_2 x_2+\ldots+\beta_p x_p+\varepsilon \qquad (1)$$

where:

- **y** is the observed value of the response
- β_0 is the constant term (intercept)
- β_i is the coefficient of the variable xi
- **p** is the number of independent variables
- ε is the error term

Assumptions

It is assumed that the collected data is a good representative of the population it is coming from. The

error term is assumed to be normally distributed with mean zero and unknown variance σ^2.

The matrix notation of equation 1 is:

$$Y = \beta X + \varepsilon \tag{2}$$

where:

- **Y** is nx1 column vector of the observed response value
- β is px1 column vector of regression coefficients of the independent variables
- **X** is {nx(p+1)} matrix of independent variables including the intercept
- ε is nx1 column vector of error terms

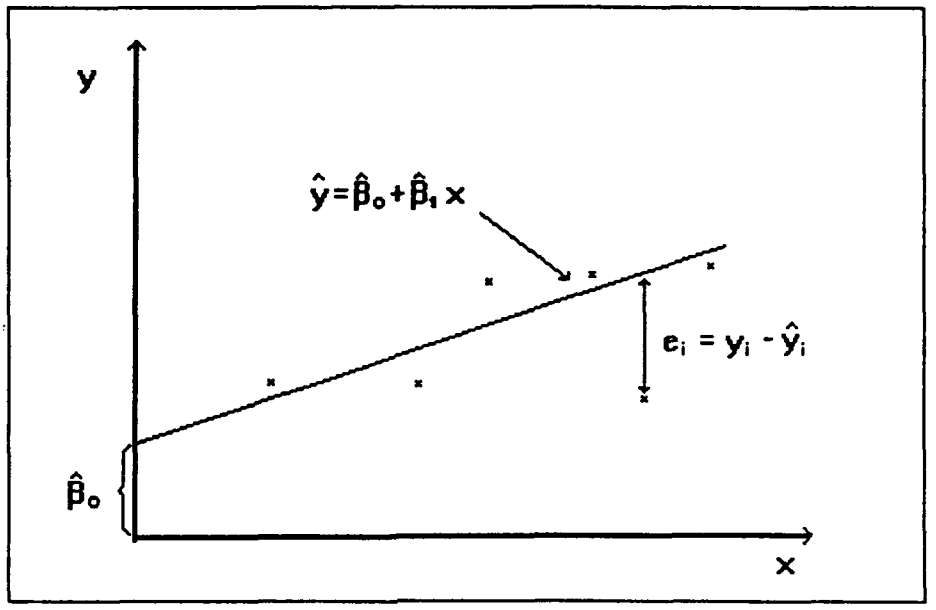
The least squares method is based on the criteria of minimizing the sum of the squared errors of prediction, that is, the sum of the squares of the observed values minus the corresponding prediction value.

$$\min \sum_{i}^{n} (e_i)^2 = \min \sum_{i}^{n} (y_i - \hat{y}_i)^2 \tag{3}$$

where:

- e_i is the residual of the observation i
- y_i is the observed response for the observation i
- $\hat{y}_i$ is the predicted value for observation i

The graphical representation of the least squares method for the two dimensional case is given in Graph 2-1.



Graph 2-1.

Least Square estimates of the regression equation is the best among the unbiased estimators (Guttman, 1982:6-21).

III. LITERATURE REVIEW

Regression

Linear regression is a statistical model-building tool that utilizes data and the relationships between two or more quantitative variables to construct a mathematical expression in order to predict the value of one variable from the other, or others. This mathematical expression or in other words regression model can, with a certain degree of accuracy, predict the level of response of the associated phenomena, given a set of predictor values.

The term "regression" emerged from Galton's studies of inheritance in biology in the late 1800's. In his particular example Galton mentioned that tall fathers had tall sons, but not as tall on average as the fathers. The same way, short fathers had short sons, but not as short on average as the fathers. The tendency of the average characteristic of the selected group in the next generation toward the mean of the population, rather than reproducing the averages of their fathers, Galton called regression-

regression toward the mean. Thus the term regression was born (Mosteller and Tukey, 1977:262).

In the real world, the analyst is concerned with the relationship between more than two variables to construct a mathematical expression in order to predict the value of one variable (called the response variable) given the others (called the independent or predictor variables). Unfortunately, it is often difficult to determine the "best" set of predictor variables to include in a linear regression model. All methods in the literature have certain disadvantages that can interfere with the process or in some cases, make it hard to implement the selected subset selection criteria.

Subset Selection

Subset selection is a subarea of regression analysis concerned with choosing variables from the given pool of predictive (independent) variables to include in the regression model.

The problem of determining the "best" subset of a given pool of variables has long been of interest to applied statisticians and because of the availability of high-speed computers in recent years, this problem has received

considerable attention in the recent statistical literature. The problem of selection a subset of independent variables is mainly influenced by the set assumptions. That is, it is assumed that a) the analyst has data on a large number of potential variables which include all significant variables and some other extraneous variables. b) the analyst has available "good" data on which to base the final conclusions. In practice lack of satisfaction of these assumptions may make the performed subsets selection analysis a meaningless exercise (Hocking, 1976:2).

Assuming the analyst has the complete set of the variables, in order to make the regression equation useful for predictive purposes he should want the model to include as many real predictors as possible so that reliable fitted values can be determined (Drapper and Smith, 1966:163). On the other hand, the analyst also wishes to reduce the number of independent variables to be used in the final model. The reasons for this are that a regression model with a large number of independent variables is hard to maintain, and that further regression models with a limited number of independent variables are easier to work with and understand. Having a large number of independent variables in the final model increases the risk of including extraneous variables which behave like the error term. Finally, the presence of many highly correlated independent variables may add little to the predictive ability of the

model while substantially increasing the sample variation of the regression coefficients and roundoff errors (Netter and others, 1990:436).

There is no unique statistical procedure for finding the "best" subset and algorithms for finding best-fitting subsets of variables to a set of data require search strategies and computational algorithms. Search strategies can be divided conveniently into those which guarantee to find the best fitting subset of some or of all sizes, and the "cheap" methods which sometimes find the best-fitting subset (Miller, 1984:391).

All-Subsets Regression

All-subsets is a very direct method, which involves estimating all possible subset regression equations. For a pool consisting of p independent variables p equations (models) including only one independent variable, $\binom{p}{2}$ equations including 2 independent variables and so forth until $\binom{p}{p} = 1$ equation including all variables were examined. Total number of equations examined for p

independent variables is 2^p-1 (Hawkins and Weber, 1980:460). Since this method examines all-possible models it a needs long computational time. Thus it requires high-speed computers. With current computer support it is not feasible to employ this method for p>20. For a variable set of 20 these are $2^{20}-1 = 1,048,575$ models that need to be examined, and for p=25 there are $2^{25}-1 = 33,554,432$ models that need to be examined.

Miller refers to all-subsets method as guaranteed to find the best-fitting model (Miller, 1984:391), but all-subsets selection is only guaranteed to find the best model if all significant predictors are considered; if the set under consideration doesn't include all significant variables, then the all-subsets approach can not find the "best" overall model but will provide the best model for variables considered (Woollard, 1993:14).

There are different subset selection criteria in the literature employed by all-subsets method. In this thesis effort the following are covered:

1. Maximum Coefficient of Multiple Determination (R^2)
2. Maximum Adjusted R^2 or Minimum MSE
3. Minimum Mallow's Cp
4. Mimimum Prediction Sum of Squares (PRESSp) or Minimum Sp

1. Maximum Coefficient of Multiple Determination R^2

The coefficient of multiple determination denoted by R^2 is defined as follows:

$$R^2 = \frac{SSR}{SST} = \frac{\Sigma(\hat{y}_i - \bar{y})^2}{\Sigma(y_i - \bar{y})^2} \qquad (4)$$

where;

SSR is sum of squares of regression

SST is the total sum of squares

$\hat{y}_i$ is the prediction value of y_i

$\bar{y}$ is the mean of y

y_i is the actual value of y for observation i

R^2 measures the proportionate reduction of total variation in y. When we look at R^2 values we would like to select models with large R^2 value. There is a pitfall in this criteria, because adding a variable to the model increases R^2, therefor a model including all variables has the largest R^2 value. That characteristic of this criteria voids its applicability in the subset selection.

2. Maximum Adjusted R^2 or Minimum MSE

Since R^2 keeps increasing with adding new variables in the model, the use of the adjusted coefficient of multiple determination R^2 has been suggested as a criteria, which

takes the number of parameters in the model into account through the degrees of freedom.

$$R_a^2 = 1-(\frac{n-1}{n-p})*\frac{SSE}{SST} = 1-\frac{MSE}{\frac{SST}{n-1}} \qquad (5)$$

SST/(n-1) is fixed for given y observations, because of this reason R_a^2 increases if MSE decreases. Hence R_a^2 and MSE are equivalent criteria (Netter and others, 1990:446). Minimum MSE or Maximum R_a^2 is one of the widely used criteria in practice.

3. Minimum Mallow C_p

Mallow C_p is an approximation of the Mean Squared Error of Prediction (MSEP). It is calculated using the following equation:

$$C_p = \frac{SSR}{S^2} - n + 2*p \qquad (6)$$

where:

SSR is the regression sum of squares

S^2 is an estimate of the variance

n is number of data points (sample size)

p is number of parameters (including intercept)

There are two applications of this criteria in the subset selection.

Application 1. The theoretical expected value of C_p is p. Thus, the C_p value of models with little bias will

tend to be Cp~p. The model with C_p value closest to p will be selected as the "best" model.

Application 2. The other application of the Cp criteria in the subset selection is to choose the model having Minimum Cp value. The models with small Cp values have small total mean squared error, therefor the model with the smallest Cp is selected to be the best.

The application #1 is hard to automate, while application #2 is easy to automate. For this reason application #2 is employet in this thesis.

4. Minimum PRESSp or Minimum Sp Criterion

PRESSp (Prediction Sum of Squares) like the C_p criterion is an approximation of the MSEP. Its formula is:

$$Sp = \frac{SSE}{(n-p)*(n-p-2)} \qquad (7)$$

where:

SSE is sum of squares of error

n is the sample size

p is the number of parameters

Models with small Sp values are considered to be good candidate models because they have small prediction errors. This method has received considerable praise in recent years.

Stepwise Procedures

These procedures do not involve evaluating all-possible regression equations. The stepwise procedures discussed in this thesis effort are:

1. Backward Elimination Procedure (BE)
2. Forward Selection Procedure (FS)
3. Stepwise Regression Method

1. Backward Elimination Procedure

This method is a suboptimal procedure, since it doesn't calculate all-possible models. The steps in this procedure can be described as follows:

a. A regression equation containing all variables is calculated.

b. The partial F-test is computed for every variable in the model treated as though it is the last variable to enter the regression equation.

c. The lowest partial F-test value, F_L, is compared with a preselected significant level F_o.

d. If $F_L < F_o$ remove the corresponding variable from consideration and go to step b.

e. If $F_L > F_o$ conclude that this is the final model.

2. Forward Selection Procedure

Backward elimination procedure begins with the largest model and subsequently reduces the number of variables in the model until a decision is reached on the equation to be used. The forward selection procedure works from the other direction. It begins with the null model. The steps can be summarized as follows:

a. Calculate first order linear equation for each of the variables in the pool.

b. Calculate the F* statistic for each model and the X variable with the largest F* value is the candidate to enter the model, say X_4.

c. If F* of $X_4 > F_o$ the variable is entered into the model.

d. Now, linear equations with two variables, where X_4 is one of the pair is fit and the corresponding F* values are computed.

e. If the largest F* value > F_o then these variables are entered into the model. Steps d and e are followed for the other variables until $F^* < F_o$.

f. If $F^* < F_o$ it is concluded that the previous model is the final model.

3. Stepwise Regression Method

There is a pitfall in Backward Elimination and Forward

Selection procedures. A variable which is significant at one step may turn out to be insignificant in the following steps and because there is no elimination for the variables already in the model for Forward Selection procedure, that variable which turned to be insignificant will be left in the model. The same problem occurs for the Backward Elimination procedure. A variable which was eliminated because it was considered insignificant may turn out to be significant in the succeding steps, but because of no addition of the variables to the model it is not possible to include that significant variable in the final model. The stepwise regression method was developed to eliminate this problem. This method is a combination of the previously mentioned two methods. It can be considered as a Forward Selection method employing Backward Elimination procedure after the addition of a new variable in the model. Miller refers to these methods as a "cheap" methods, because it is not guaranteed that the final model is the "best".

Miller's Method

The idea of augmenting the variable pool with known extraneous random variables was first introduced to the

literature by Miller in 1984. Later in 1990 Miller provided more detailed information about this idea (Miller, 1990:84-85). Woollard in 1993 applied this augmentation procedure and named this method Miller's Method (Woollard, 1993:21-22). In this method Woollard augmented the variable pool with an equal number of "dummy", known extraneous random variables. These random variables are generated from standard normal distribution. Later Forward Selection procedure was employed until the first known extraneous random variable was included in the model. Subset selection procedure stopped and discards the model including the known extraneous random variable, and used the previous model. The other variables not included in the model were considered insignificant.

IV. METHODOLOGY AND MODEL DEVELOPMENT

OBJECTIVE

The goal of this thesis research is to introduce and study a modification of Miller's Method which we call the Modified-Miller's method (MM method), study two step subset selection procedures, one of which applies Miller's Method in the first step and employs Minimum MSE or Minimum Sp or Minimum Cp in the second step and the other of which employs Minimum MSE or Minimum Sp or Minimum Cp in the first step and applies Miller's Method in the second step. The results of all techniques will be compared including the results of the previous simulation studies done by Hansen in 1988 and by Woollard in 1993. In the researches mentioned above, Minimum MSE, Minimum Sp, Minimum Cp and Miller's method were studied.

LIMITATIONS

Two kinds of limitations were experienced in this simulation study:

(1) Limitations based on the assumptions of the

applied technique.

Since least squares regression is extensively employed in this thesis research the result and the conclusions are valid within the limitations of these assumptions. These assumptions can be summarized as follows: data is assumed to be representative of the population, the error term is assumed to be independent and identically distributed with mean zero and variance σ^2 (Woollard, 1993:25)

(2) Computer limitations.

In this thesis research over 80,000 models were examined. Because of the allocation problems which occurred in the computer system, the research area was restricted and the Modified Miller's method was run with fewer replications than what is recommended.

OVERVIEW

The methodology and approach in this thesis will be consistent with that used by Hansen and Woollard so that it will be possible to compare the results of the methods employed in this research with the results of the previous two studies. This thesis effort aims to extend the process

of finding better subset selection methods started by Hansen in 1988 and later continued by Woollard in 1993. It is possible to divide this research effort mainly into four areas of focus:

(1) Data generation.

(2) Introduction and the development process of the Modified-Miller's method.

(3) Model selection by employing different subset selection methods.

(4) Generation of performance measurements and evaluation of the subset selection methods.

The data used in this study was generated by Hansen and later corrected by Woollard. These data sets were generated with known statistical properties.

For the application of the Modified-Miller's method SAS Stepwise procedure and FORTRAN routines were employed and in the two stage model selection process SAS all-subsets and Stepwise procedures were used along with the FORTRAN codes that pick the best model among the generated ones.

Two different performance measurements were calculated. The first one, designated PM, calculates the percentage of the correct variables selected in the given model. The second performance measure, designated FM, calculates the percentage of the perfect models (for this study the perfect

model consist of set {X1 X2 X3}) to the number of all models.

For the evaluation of the employed methods, experimental design was constructed based on the RSM (Response Surface Methodology) to determine the impact of the specific statistical properties of the data.

OVERVIEW OF DATA GENERATION PROCESS

The data used in this simulation study was generated by Hansen in 1988 (Hansen 1988:34-37). Later in 1993 Woollard made a few corrections in the original data (Woollard 1993:27-31). The data used in this simulation study is the revised version. An overview of that data generation process is given in the following section.

The data needed for this simulation study was created with certain characteristics considering the design point. The design points were established according to the RSM (Response Surface Methodology). This approach to data generation provides the advantage of knowing the characteristics of the data. Those characteristics in the experimental design are called factors and in this study

they are given in the next section.

Factors

In the data generation for this simulation study six potentially significant statistical properties were considered as factors. For each factor low and high settings were established, therefor a 2^6 full factorial design was used. The six factors employed in this design were:

1. The Number of Extraneous Variables.

Extraneous variables are those independent variables which are in the variable pool, but which actually are independent of the dependent variable and act as noise if included in the prediction model. In this design, at the low setting the number of extraneous variables is 1 and at the high setting, 3. They are denoted E1, E2 and E3.

2. The Correlation Between Real Predictors.

Real predictors are denoted X1, X2, X3 and X4. These are independent variables used in generation of the dependent variable. At low setting the variables are independent from each other, in another words orthogonal

(having zero correlation) and at high setting they are highly correlated with a correlation of 0.9.

3. The Variance of The Extraneous Variables.

The low setting is 1 and the high setting is 100.

4. The Variance of The Real Predictors.

The low setting is 1 and the high setting is 100.

5. The Sample Size.

The low setting for the sample size is 10 and the high setting is 20. Sample size less than 10 cannot be used in computing Sp criteria (Hansen, 1988:35-36)

6. The Variance of the Error Term.

The low setting for the variance of the error term is 0.0625 and the high setting is 0.25.

Order	Factor Description	Values		Factor Symbol	
		Low	High	Low	High
1	Number of extr.var.	1.0	3.0	a	A
2	Corr. of real pred.	0.0	0.9	b	B
3	σ^2 of extr. var.	1.0	100.0	c	C
4	σ^2 of real pred.	1.0	100.0	d	D
5	Sample Size	10.0	20.0	e	E
6	σ^2 of the error term	0.0625	0.25	f	F

Table 4-1.

Summary table for the factors used in data generation.

In order to make the representation of factors easy through out the thesis, factors are expressed with the respective factor symbol.

Design Point	Data Files	Factor Settings
1	01.dat	abcdef
2	02.dat	Abcdef
3	03.dat	aBcdef
4	04.dat	ABcdef
5	05.dat	abCdef
6	06.dat	AbCdef
7	07.dat	aBCdef
8	08.dat	ABCdef
. . .	. . .	. . .
63	63.dat	aBCDEF
64	64.dat	ABCDEF

Table 4-2.

Table 4-2 shows the order of factors according to the design point. Capital letter shows high settings, lower case letters represent low settings.

Data Generation

The data for real predictors and the dependent variable were generated from the following equation:

$$Y_i = X1_i + X2_i + X3_i + X4_i + \varepsilon_i \qquad (8)$$

where;

Y_i is the response (dependent variable)

$X1_i \ldots X4_i$ are randomly generated predictors

ε_i is the noise term

In order to have a more realistic simulation of the real world, after the generation of Y_i, $X1_i$, $X2_i$, $X3_i$, $X4_i$ with the characteristics of the design point i, the $X4_i$ term was dropped from the variable pool. In the real world we may not be aware of a significant term or we may be aware of it but not able to collect data about it and include it in the variable pool. In addition to these real predictors 1 or 3 extraneous variables have been included in the variable pool. The number of generated data for a specific design point is consistent with the sample size factor of this

design point. The error term (ε_i) is also included in the data generation for the better representation of the real world.

Data Sets

For each design point 60 data sets have been generated. It is possible to consider each set as a sample from a population. According to the sample size factor settings in the experimental design, this sampling is done with a sample of size 10 for low settings and a sample of size 20 for high settings.

PERFORMANCE MEASUREMENTS

In regression analysis the first concern is to find a model having no extraneous variables, and the second concern is to find a model including the right number of real predictors in order to minimize deviation from the perfect

model. In the real world it is not possible to know what is the perfect model, but it can be described as a model which best describes the whole population. To achieve these goals, in this research effort two types of measurements were employed in order to evaluate the success of the applied subset selection method.

1. Performance Measurement for Real Predictors (PM).

This measurement deals with the first concern; having no extraneous variables or in other words having only real predictors in the selected model. The equation for the PM value was set as follows;

$$PM = \frac{number\ of\ correct\ variables\ chosen}{number\ of\ variables\ chosen} \qquad (9)$$

In the real world it is not possible to know which variables are real and which are extraneous, therefor it is not possible to compute the PM value. But in the simulation, where these factors are under control, PM values are computed to evaluate the applied subset selection criteria. PM takes into account the number of the extraneous variables

along with the number of the real predictors. It is worse to select a model with only two predictors of which one is extraneous, than it is to select a model containing four variables of which one is extraneous (Woollard, 1993:34). The PM values for these two cases are;

$$\textit{Case one}: \quad Y1 = X1\ E1 \quad \rightarrow \quad PM = \frac{1}{2} = 0.5$$

$$\textit{Case two}: \quad Y2 = X1\ X2\ X3\ E1 \quad \rightarrow \quad PM = \frac{3}{4} = 0.75$$

Each model has one extraneous variable, but the second model is logically preferable to the first since it includes a larger number of real predictors, and the same conclusion was arrived at with the computed PM value.

One can think of a model containing only one predictor and it is a real one; and compare it with a model containing four predictors, three of which are real with the fourth one being an extraneous variable, and a third model containing

three predictors, all of which are real. The PM values are;

$$\textit{Model number } 1: \quad PM_1 = \frac{1}{1} = 1.00$$

$$\textit{Model number } 2: \quad PM_2 = \frac{3}{4} = 0.75$$

$$\textit{Model number } 3: \quad PM_3 = \frac{3}{3} = 1.00$$

At first this may not look reasonable. One may ask "Is the first model superior to the second model with the first and third models being equivalent?". In terms of the extraneous variables the answer is "Yes". These results are consistent with the goal of PM measurement. This performance measurement is designed to eliminate the extraneous variables. The PM consideration of the model

consisting of only {X1} and model consisting of {X1, X2, X3} are equivalent has been compensated for in the Full Model (FM) measurement.

2. Performance Measurement for the Full Model (FM).

This measurement deals with the second concern: finding a model which includes the right number of real predictors in order to get less deviation from the perfect model. For this study the perfect model is {X1, X2, X3}, since the data was generated from $Y_i=X1_i+X2_i+X3_i+X4_i+\varepsilon_i$ and only {X1, X2, X3} were in the variable pool. Therefor, models different then {X1, X2, X3} have been ignored. The equation for this performance measurement is as follows;

$$FM = \frac{number\ of\ full\ models}{number\ of\ all\ models} \qquad (10)$$

The following example is given to demonstrate the computation of the FM values used to evaluate the performance of the applied methods in this thesis effort:

For each design point 60 data sets were established. Employing any of the subset selection criteria used in this study provides us with a model, which is assumed to be the best one for that specific data set. Therefor for each design point there are 60 models on hand. (Null models,

having no independent predictors, are also considered as a model.) Assume that 35 of these 60 models are {X1 X2 X3}. The FM value for this given design point is 35/60 = 0.583.

RESULTS OF PREVIOUS SIMULATION STUDIES

In the previous two subset selection simulation studies two performance measurements were employed.

1. Performance measure (PM) for the percentage of correct variables.

The PM values described in previous sections are used by Hansen to evaluate the performance of Minimum MSE, Minimum Sp, and Minimum Cp (Hanser, 1988:39). In 1993 Woollard used the same performance measurement to evaluate Minimum MSE, Minimum Sp, Minimum Cp, and Miller's Method (Woollard, 1993:39). In his research, Woollard reran the three methods studied by Hansen after the correction of the data files. Because of this correction in the data files, only Woollard's PM results were covered in this section. The experimental design used to examine the behavior of the employed subset selection criteria to the statistical

characteristics of the data will be explained in detail in chapter V, but in this stage it can be told that this experimental design is based on RSM, where the following equations are the models of PM, given characteristics (factors) of the data. Woollard's results for PM measurement are (Woollard, 1993:40):

Minimum MSE.

$$PM_{MSE} = 0.78 - 0.10(A) + 0.0023(D) + 0.006(E) + 0.0062(F) + 0.003(AE) + 0.003(AF) - 0.003(DF) - 0.006(EF) - 0.003(AEF)$$

Minimum Sp.

$$PM_{Sp} = 0.85 - 0.07(A) + 0.002(D) + 0.007(F) + 0.002(AD) + 0.006(AE) - 0.003(DE) - 0.007(AF) - 0.002(DF) - 0.005(EF) - 0.002(ADF) - 0.006(AEF)$$

Minimum CP.

$$PM_{Cp} = 0.84 - 0.07(A) + 0.003(D) + 0.007(E) + 0.008(F) + 0.002(AD) + 0.006(AE) + 0.003(DE) + 0.008(AF) - 0.003(DF) - 0.005(EF) - 0.002(ADF) - 0.006(AEF)$$

Miller's Method.

$$PM_{Miller} = 0.88 - 0.04(A) + 0.01(B) + 0.02(E) + 0.01(AB) + .0.008(AE) - 0.008(BE) - 0.008(BCEF)$$

Method / Factors	Minimum MSE	Minimum Sp	Minimum Cp	Miller's Method
A(# of ext. var)	-0.1	-0.7	-0.07	-0.04
B (ind.corr)	0	0	0	+0.01
C($\sigma^2$of ext.var.)	0	0	0	0
D($\sigma^2$of ind.var.)	+0.0023	+0.002	+0.003	0
E(sample size)	+0.006	+0.007	+0.007	+0.02
F(error term)	+0.0062	+0.007	+0.008	0
Intercept	+0.78	+0.85	+0.84	+0.88

Table 4-3.

Main factor Coefficients of Effects by Method for PM measurement

Performance Measure of Model Accuracy

For the performance measure of the model accuracy, Hansen and Woollard used Theoretical Mean Square Error of Prediction (TMSEP) (Hansen, 1988:44)and (Woollard, 1993:50). TMSEP is defined as follows;

$$TMSEP_{k,m} = \frac{\sum_{t=1}^{n_k} (y_t - \bar{y}_{k,m})^2}{n_k - p_{k,m}} \qquad (11)$$

where:

$\mathbf{TMSEP_{k,m}}$ is the TMSEP for data set k using the subset selection technique m

$\mathbf{Y_t}$ is the theoretical conditional mean of Y calculated from the model that data was generated from.

$\mathbf{Y_{k,m}}$ is the predicted value of Y using technique m to the data set k

$\mathbf{n_k}$ is the sample size of the data set k

$\mathbf{P_{k,m}}$ is the number of predictors in the model applying technique m to the data set k

In this research for the performance of the model

accuracy the Full Model(FM) measurement is employed. The reasons for employing this performance measurement are;

(1) Calculation of TMSEP is based on sampled data ($Y_{k,m}$, n_k, $p_{k,m}$), which means that this performance measure was influenced by the sampling error. In this performance measurement there is a risk to end up with a model including many extraneous variables and have an overfitted model.

(2) In the real world, it is not possible to calculate FM value because the perfect model (model including all real predictors and no extraneous ones) is not known, and actually the goal of the regression analysis is to find that perfect model or the closest one. In this simulation study the perfect model is already available, because the data was generated from the model established by the researcher. Using this advantage FM values are easily computed employing equation (10). FM measurement is very conservative, since it is considering models consisting of only {X1, X2, X3}, but this performance measure is free from sampling error.

As it was mentioned in the beginning of this section, Hansen and Woollard employed TMSEP for model accuracy. In order to compare the results of the previous studies with the results of the subset selection technique applied in

this research, Woollard model accuracy computations were rerun according to FM criteria. The results were shown and compared with the results of the new techniques in chapter V.

NEW SUBSET SELECTION METHODS STUDIED IN THIS RESEARCH

Seven different approaches were examined in this thesis effort for the subset selection. The first six of them are two stage subset selection technique and the seventh one is Modified Miller's Method (MM Method). These subset selection technique can be listed as follows:

1. Miller's & MSE Method (MLRMSE method)
2. Miller's & Sp Method (MLRSp method)
3. Miller's & Cp Method (MLRCp method)
4. MSE & Miller's Method (MSEMLR method)
5. Sp & Miller's Method (SpMLR method)
6. Cp & Miller's Method (CpMLR method)
7. Modified Miller's Method (MM method)

Two Stage Subset Selection Process Where Miller's Method is Used for Screening.

The first three methods are two stage subset selection techniques where, in the first stage Miller's method is employed as a screening method and in the second stage Minimum MSE or Minimum Sp or Minimum Cp is employed as a final subset selection technique to the variable pool obtained by the first stage (Miller's Method). This procedure can be illustrated as follows:

Assume that the original variable pool includes X1, X2, X3, E1, E2 and E3. Miller's Method is applied as a screening process in the first stage and the model obtained include X1, X2, X3 and E2 variables. In the second stage for the final subset selection process Minimum MSE, Minimum Sp or Minimum Cp is employed using variable pool X1, X2, X3 and E2.

Two Stage Subset Selection Process Where Miller's Method is Used For Final Subset Selection.

The second three two stage subset selection methods listed in page 39, which are the 4th, 5th and 6th methods

employs Minimum MSE or minimum Sp or Minimum Cp for screening in the first stage and for the final subset selection process in the second stage Miller's Method is employed.

Modified Miller's Method (MM Method)

The basic idea in the Miller's Method is this: since extraneous variables have no relation with the dependent variable in reality, the correlation should be zero; because of the sampling error the sample correlation matrix may not show zero correlation between dependent and extraneous variables, and applied techniques for finding the best model may include extraneous variables in the final model. In order to minimize this undesirable effect, the variable pool is augmented with known extraneous random variables. When the subset selection procedure (Stepwise with Forward selection was used in Miller's Method) first picks one of these known extraneous random variables, the selection procedure stops and the previous model (model including no known extraneous random variables) is selected as the final model. In reality Miller's Method is a simulation of extraneous variables, because randomly generated known random variables are exposed to the same sampling error that

extraneous variables are; for small sample size this error is expected to be large and with the increased sample size this error is expected to decrease. Because Miller's Method is a simulation, like other simulation technique it should be run multiple times. The specific reason for the need to run more then once is this: Assume that because of the sampling error the first variable picked by the selection procedure could be one of the known extraneous random variables. In this case the selection procedure stops and the final model is concluded to be the null model. With multiple runs the effect of this undesired result will be minimized. Modifications in the Miller's method lead us to a new method called Modified-Miller's method (MM method). In the application of the MM method there are four questions which need to be answered.

(1) What is the best number of known extraneous random variables to be used in the augmentation of the variable pool?

(2) How many runs should be performed?

(3) How to select the best model?

(4) How to decide when the best model is the null model? (The null model is best when the pool is all extraneous. The question is how to conclude that all variables in the pool are extraneous.)

The answers follow:

1. Number of known extraneous random variables (augmentation coefficient).

Assume that there is a pool of 4 variables, 3 of them are real predictors and 1 is extraneous (which we can know only in a simulation). This pool is augmented with 4 known extraneous random variables. Suppose that the subset selection process has reached the stage where the selected variables are all real ones and that all extraneous variable, including the augmented ones, have the same chance of being picked next. Then, the conditional probability that the extraneous variable is included in the model is $1/(1+4)=0.20$ and the probability that one of the known extraneous random variables is chosen is $4/(1+4)=0.80$. Now instead of augmenting with 4 let us augment the pool with 8 known extraneous variables. The probability that the extraneous variable is included will be $1/(1+8)=0.11$ and the probability that one of the known extraneous random variables is chosen is $8/(1+8)=.89$. The critical point in the decision on the number of known random variables is this: if there are fewer known extraneous random variables than necessary, the probability of having extraneous variables in the model is high. If there are more known extraneous random variables than are needed, the probability

that some the real predictors are not included in the model is high. In order to find the optimum number of known extraneous random variables each data set was augmented by 0.5, 1.0, 1.5 and 2 times the number of variables a specific data set has.

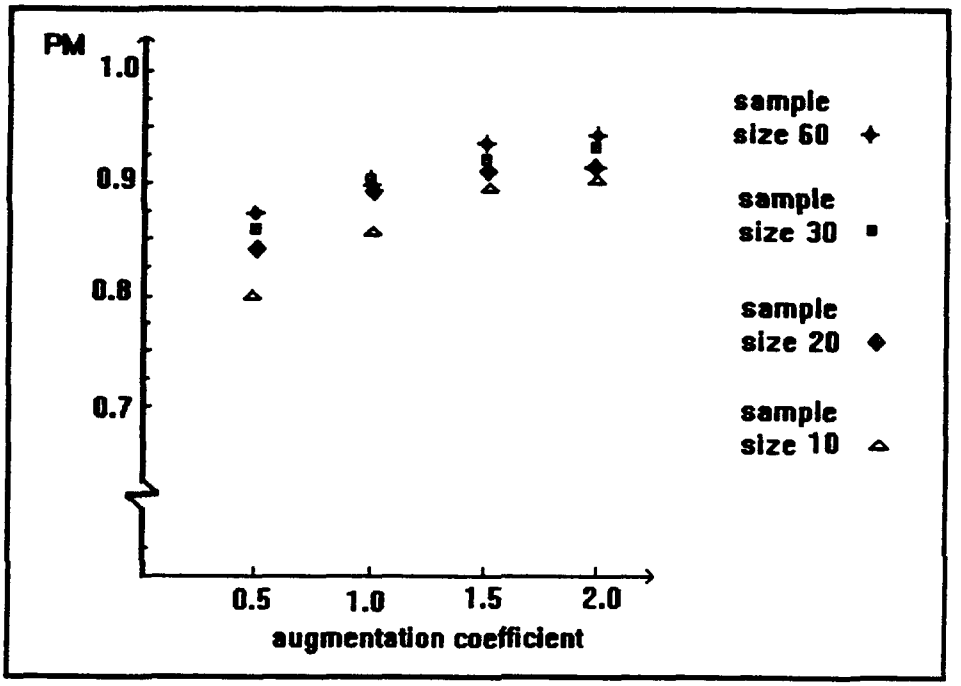
These numbers are designated as augmentation coefficients. The MM method was run for each set with each augmentation. To be able to examine the effect of the sample size more effectively, data sets of 30 and 60 samples were obtained by joining 3 sets of sample size 10 or 20 of the original data. Therefor, 64x60=3840 data sets of size 10 or 20 and 64x20=1280 data sets of size 30 or 60, as total 5120 data sets were examined for each augmentation coefficient. For the measurement of the performance PM and FM measurements were employed.

The PM values of the MM method for different augmentation coefficients was given in the Table 4-4. For better representation, the data in column 5 (average PM values) was graphed (Graph 4-1). The data for this column is the average of the average PM values of 1 and 3 extraneous cases. Therefor, only sample sizes were considered, because in the real world only this factor is under the control of the experimenter.

Smpl. Size	Augm. coeff.	Avrg. PM val. of models obtained from sets having 1 ext. var.	Avrg. PM val. of models obtained from sets having 3 ext. var.	Avrg. PM values
10	0.5	0.8737217	0.745335	0.8095536
	1.0	0.9042049	0.8105713	0.8573881
	1.5	0.9249750	0.8391179	0.8820465
	2.0	0.9350211	0.8576428	0.8963320
20	0.5	0.8971385	0.8017612	0.8494499
	1.0	0.9286529	0.8675144	0.8980837
	1.5	0.9474303	0.9038717	0.9256510
	2.0	0.9232731	0.9127891	0.9180311
30	0.5	0.8885906	0.8405158	0.8645532
	1.0	0.9361144	0.8884765	0.9122955
	1.5	0.9331758	0.9241160	0.9286459
	2.0	0.9513009	0.9421828	0.9467419
60	0.5	0.9039543	0.8608187	0.8823865
	1.0	0.9473114	0.8706017	0.9089566
	1.5	0.9581975	0.9120995	0.9351485
	2.0	0.9648063	0.9301523	0.9474793

Table 4-4.

The PM values of models obtained by using different augmentation coefficients.



Graph 4-1.

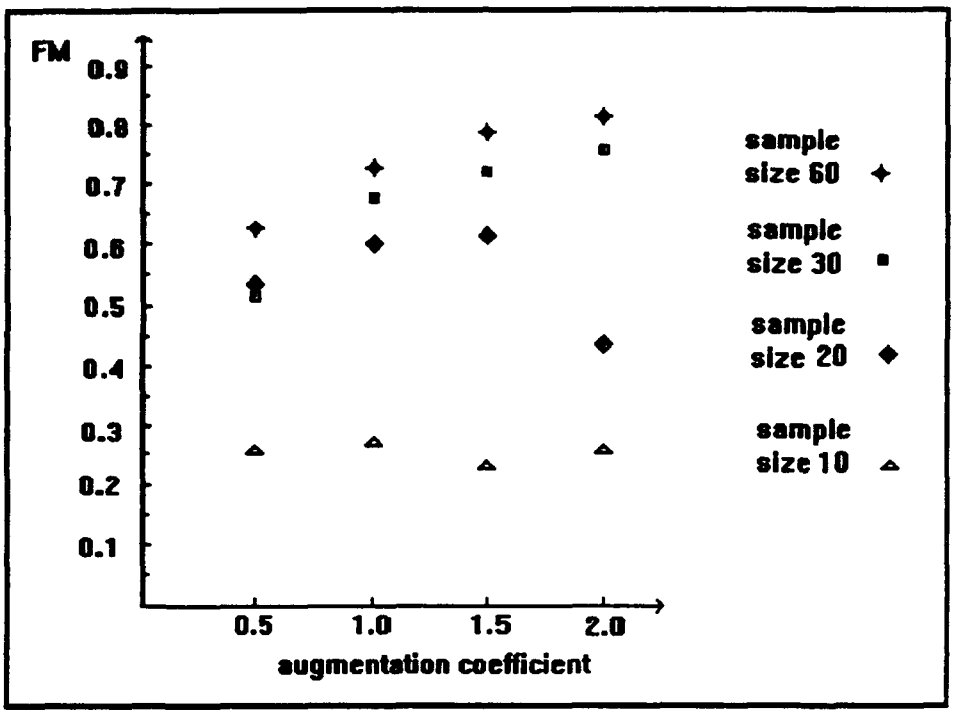
The PM values of Table 4-4 column 5 were graphed to demonstrate the relation between sample size, the augmentation coefficient and PM measurement.

The FM values of MM method were displayed in the table 4-5. The average FM values (column 5) were graphed (Graph 4-2) considering sample size and the augmentation coefficients.

Smpl. size	Augm. coeff.	Avrg. FM val. of models obtained from sets having 1 ext. var.	Avrg. FM val. of models obtained from sets having 3 ext. var.	Avrg. FM values
10	0.5	0.320	0.192	0.256
	1.0	0.322	0.197	0.260
	1.5	0.288	0.171	0.230
	2.0	0.335	0.164	0.250
20	0.5	0.600	0.473	0.537
	1.0	0.670	0.530	0.600
	1.5	0.684	0.551	0.618
	2.0	0.278	0.579	0.429
30	0.5	0.565	0.491	0.528
	1.0	0.709	0.644	0.677
	1.5	0.671	0.778	0.724
	2.0	0.750	0.756	0.753
60	0.5	0.725	0.523	0.624
	1.0	0.794	0.656	0.725
	1.5	0.825	0.753	0.789
	2.0	0.825	0.803	0.814

Table 4-5.

The FM values for models obtained for different augmentation coefficients.



Graph 4-2.

This graph demonstrates the FM values of Table 4-5 column 5.

The results of PM value measurement shows that when the number of known extraneous random variables increases the PM value keeps increasing, but this is not a constant increase, and diminishing returns were observed.

The results of FM measurement show that the optimum number of known random variables depends on the sample size.

This is a good result, since the experimenter in the real world can only control the sample size. For 1 and 3 extraneous variables it was observed that for sample size 10 the maximum FM value occurs for number of known extraneous random variables which is the same with the number of variables in the pool. For sample size 20 maximum FM value occurs for 1.5 augmentation coefficient. For sample size 30 and 60 maximum FM value occurs near 2 augmentation coefficient.

2. Run Numbers

Since the MM method is a kind of simulation each run can be considered as one sample. The more runs, the more accurate is the final model. The recommended number of runs for MM method can be computed using the expected value and the standard deviation of the Binomial Distribution. The conditions for Binomial Distributions are:

1. The experiment consists of a sequence of n trials, where n is fixed in advance of the experiment.

2. Each trial can result in one of the same two possible outcomes, denoted by success (S) or failure (F).

3. Trials are independent.

4. The probability of success is constant from trial to trial.

In MM method run number is set ahead of time, say n (condition 1 holds). Each run can end up with null model (success) or with a non-null model (failure), so, condition 2 is also satisfied. In MM method each run is independent from the others thus, condition 3 is satisfied. The probability of having null model (P(null)=number of known extraneous variables/all variables in the augmented pool) is constant for each run so, condition 4 holds.

This decision process for run number using binomial distribution is demonstrated as follows:

Assume that all the variables in the given set are extraneous and the number of variables in the set is V. This set is augmented with r number of known extraneous variables. Thus, the probability of having null model is,

$$P(null) = \frac{r}{V+r}$$

The mean and the variance for a Binomial Distribution can be computed as follows:

$$E(S) = np \qquad V(S) = np(1-p) \qquad (12)$$

where:

S is the number of successes.

n is the number of trials.

p is the probability of success in a trial.

Now, computing the mean and the variance and the standard deviation for the given case yields:

$$Bin(n, \frac{r}{V+r})$$

$$E(null) = n(\frac{r}{V+r})$$

$$V(null) = n(\frac{r}{V+r})(\frac{V}{V+r})$$

$$\sigma = \frac{\sqrt{nrV}}{V+r}$$

Since observations should be positive, the 3 standard deviation to the left of the mean value should be at least zero;

$$\mu - 3\sigma = \frac{nr}{V+r} - 3\frac{\sqrt{nVr}}{V+r} > 0$$

$$\therefore \quad nr > 3\sqrt{nVr}$$

$$n^2r^2 > 9nVr$$

$$n > 9\left(\frac{V}{r}\right)$$

If the standard deviation is reduced from 3 to 2 or 1, then, the required number of runs will be less but, this will reduce the confidence of concluding that the model is null or non-null. For this reason the decision of number of runs is left to the experimenter based on his decision of confidence level.

In this research 6 runs were used because of dealing with large number of models and having computer allocation problems, with the tradeoff having less confidence level. For 6 runs 64x60x6=23040 models were examined. For demonstration purpose 8 data sets with 60 runs each were used and the results were compared with the same data sets with 6 runs in chapter VI.

3. Finding The Best Model

The procedure for finding the best model is demonstrated with the help of the following example. The data used in this example comes from design point 14 and data set 31.

Model	Frequency
y = x2	7
y = x2 x3	3
y = x1 x2 x3	18
y = x1 x2 x3 E3	3
y = x1 x2 x3 E3 E2	8
Null Model	21

Table 4-6.

In this example the sample size is 10 and the variable pool {X1, X2, X3, E1, E2, E3} consists of 6 variables. This pool was augmented by 6 known random variables and the MM Method was run 60 times. The most frequent model is the null model. Let us assume for a moment that all variables

in the pool are extraneous. The probability of having a null model is P(0)=0.50. In the given example the ratio of null models to all models is 21/60=0.35 . Since this ratio is much smaller than 0.50 and since run number is large enough (60) it is possible to conclude that the final model is not null. The second most frequent model is {X1,X2,X3} therefor, it is concluded that the best model consists of set {X1,X2,X3}.

The steps in the best model selection can be summarized as follows;

- Find the most frequent model. If this is not the null model than it is the best one.

- If the most frequent model is the null model then compute the theoretical probability of having the null model with the assumption that all variables in the pool are extraneous. If the run number is small and the theoretical probability and the actual ratio of the null models to all models is close than calculate the confidence interval of your model (described in the null model section).

- If the ratio of null models is much less than theoretical value then select the second most frequent model as the best model.

4. Null Model

In some cases it would be hard to decide whether to neglect the most frequent null model and consider the second most frequent one as the best model. In such a case where theoretical ratio and the empirical ratio of the null model is close, especially for small sample size, confidence interval should be considered.

For the demonstration purposes the confidence interval for the MM method results in Table 4-6 is computed. Assume all the variables in the pool are extraneous. Then;

$$P(null) = \frac{6}{12} = .5$$

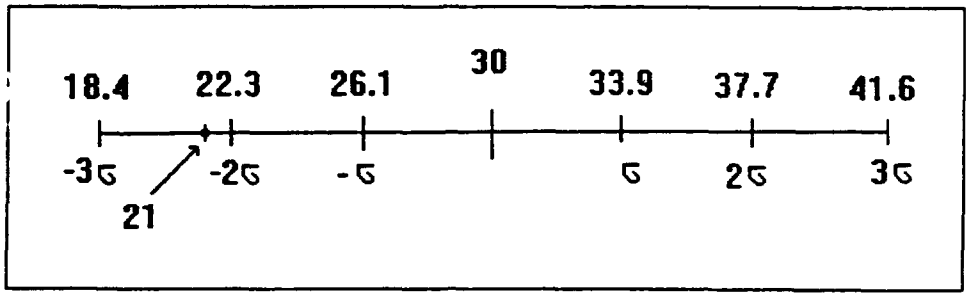
Now, the experiment turns to be a Binomial experiment because all the conditions of the Binomial Distribution are satisfied. For the given example (Table 4-6), the expected value, the variance and the standard deviation of null models is:

$$E(null) = 60*0.5 = 30$$

$$V(null) = 60*0.5(1-0.5) = 15$$

$$\sigma_{null} = 3.872983$$

These are the theoretical values assuming that all the variables in the pool are extraneous. Now, compare it with the empirical null value displayed in Graph 4-3.



Graph 4-3.

The farther to the left is the empirical value of null models from E(null), the higher is the confidence in concluding that the assumption of all of the variables extraneous is wrong. In the given example the deviation from the expected value is larger than two standard deviations. Therefor, with very high confidence it can be concluded that the assumption of all variables extraneous is wrong. Cross validation of this decision can be done by computing the probabilities of having 21 or less.

$$P(null \leq 21) = \sum \binom{60}{k} (0.5)^k (0.5)^{60-k} = 0.014$$

This small probability (0.014) of having 21 or less also indicates that the assumption is wrong.

If comparison is made between Miller's Method and Modified Miller's Method, it is possible to say that Miller's Method is a special case of Modified Miller's Method where, the augmentation coefficient is fixed at 1 and the number of runs is one.

V. Experimental Design and the Results

In this chapter two 2^6 full factorial experimental designs were established, where PM and FM values calculated for each method at each design point were used as the response value. The results of these experiments helped determine the effect of factors (statistical properties of the data) on the performance of the applied subset selection method.

Experiment

The experiment conducted in this research is the same used by Hansen and Woollard and was established according to the RSM (Response Surface Methodology) understanding. When using RSM it is convenient to use coded factors (variables). The following equation provides translating a variable from uncoded space to the coded space.

$$Z_i = \frac{X_i - \frac{High_i + Low_i}{2}}{\frac{High_i}{2} - \frac{Low_i}{2}} \qquad (13)$$

where;

X_i is the variable in uncoded space of factor i

Z_i is the variable in coded space of factor i

$High_i$ is the upper bound of the uncoded variable X_i

Low_i is the lower bound of the uncoded variable X_i

The following table shows the factors in uncoded space and the corresponding factors in the coded space.

Variable description	Uncoded variable	Uncoded		Coded variable	Coded	
		Low	High		Low	High
Num. of Extr. variables	A	1.0	3.0	Z_1	-1	1
Corr. of Ind. variables	B	0.0	0.9	Z_2	-1	1
Variance of Extr. variables	C	1.0	100	Z_3	-1	1
Variance of Ind. variables	D	1.0	100	Z_4	-1	1
Sample Size	E	10.0	20.0	Z_5	-1	1
Variance of Error Term	F	.0625	0.25	Z_6	-1	1

Table 5-1.

Variable Coding for Response Surface Methodology

In order to obtain the effect of interactions along with the main factors a 2^6 full factorial experimental design was set up. The interaction terms are simply the product of the corresponding coded main factor. Therefor, the design matrix is a 64x64 matrix where entries are -1 and 1.

PM Equations

By editing the PM.DAT file created by Woollard using STATISTIX 4.0, a 2^6 full factorial design matrix was augmented by the PM values calculated for each subset selection method at each design point. This data file was used as an input to the SAS file where the stepwise regression procedure was run to generate the following equations.

$$PM_{MLRMSE} = 0.891 - 0.050A - 0.016EF - 0.022AEF$$

$$PM_{MLRSP} = 0.895$$

$$PM_{MLRCP} = 0.882 - 0.061A - 0.019AEF$$

$$PM_{MSEMLR} = 0.873 - 0.055A + 0.021E - 0.009DE - 0.010ADE$$

$$PM_{SPMLR} = 0.952 - 0.021A + 0.013B + 0.022E + 0.10AE - 0.010BE .$$

$$PM_{CPMLR} = 0.951 - 0.021A + 0.012B + 0.024E + 0.012AE - 0.010BE$$

$$PM_{MM} = 0.929 - 0.021A + 0.008B + 0.024E + 0.010AE + 0.007ACDEF$$

The following table includes the main factor coefficient of effects by methods for PM values of Woollard research and the results of the methods examined in this thesis effort.

FACTORS / METHODS	μ	A	B	C	D	E	F
MSE	.780	−.100	0	0	.002	.006	.006
Sp	.850	−.070	0	0	.002	.007	.007
Cp	.840	−.070	0	0	.003	.007	.008
Miller's	.880	−.040	.010	0	0	.020	0
MLRMSE	.891	−.050	0	0	0	0	0
MLRSp	.895	0	0	0	0	0	0
MLRCp	.882	−.060	0	0	0	0	0
MSEMLR	.873	−.055	0	0	0	.021	0
SpMLR	.952	−.021	.013	0	0	.022	0
CpMLR	.951	−.021	.012	0	0	.022	0
MM	.929	−.021	.008	0	0	.024	0

Table 5-2.

Summery Table of the Effects of Main Factors for PM measurement.

Results for PM Measurement

1. Intercept (μ)

The highest mean PM value was calculated for the SpMLR Method (0.952), second the CpMLR Method (0.951). The MM Method has the third largest PM value (0.929) and the smallest PM value is that of the MSE method (0.78).

2. Factor A (Number of Extraneous Variables)

All methods are influenced by the number of extraneous variables, except the MLRSp method. The PM value decreases with increases in the number of extraneous variables. The most influenced method is the MSE method (-0.100). The MM Method is one of the least influenced (-0.021).

3. Factor B (Correlation of Independent Variables)

Miller's Method, SpMLR, CpMLR and MM methods are influenced by this factor.

4. Factor C (Variance of Extraneous ables)

None of the methods are influenced by this factor.

5. Factor D (Variance of Independent Variables)

This factor has an influence on MSE, Sp and Cp methods, but it is a small (0.002-0.003).

6. Factor E (Sample Size)

All methods, except MLRMSE, MLRSp and MLRCp are influenced by this factor. The MM Method is the most influenced one (0.024).

7. Factor F (Error Term)

Only MSE, Sp and Cp methods are influenced by this factor.

FM Equations

By editing the PM.DAT file created by Woollard, a 2^6 full factorial design matrix was augmented with the FM values calculated for each subset selection method at each design point. This data file was used as an input to the SAS file where a stepwise regression procedure was run to generate the following equations.

$$FM_{MSE} = 0.384 - 0.0155A + .0.078E$$

$$FM_{Sp} = 0.495 - 0.101A + 0.175E$$

$$FM_{Cp} = 0.487 - 0.102A + 0.032D + 0.173E + 0.032DF$$

$$FM_{Miller} = 0.433 - 0.064A + 0.061B + 0.042D + 0.036BD + 0.173E - 0.025BE - 0.021BDE - 0.030F + 0.019ABF + 0.027DF + 0.029BDF$$

$$FM_{MLRMSE} = 0.406 - 0.078A + 0.063B - 0.034AB + 0.035D + 0.027BD + 0.170E - 0.031AE - 0.032F + 0.035DF$$

$$FM_{MLRSp} = 0.416 - 0.082A + 0.062B - 0.033AB + 0.040D + 0.027BD + 0.170E - 0.031AE - 0.032F + 0.035DF$$

$$FM_{MLRCp} = 0.390 - 0.099A + 0.058B - 0.032AB + 0.034D - 0.025AD + 0.032BD + 0.177E - 0.039AE - 0.030F + 0.034DF$$

$$FM_{MSEMLR} = 0.443 - 0.083A + 0.062B + 0.031D + 0.034BD + 0.170E - 0.031F + 0.034DF$$

$$FM_{SpMLR} = 0.499 - 0.035A + 0.074B + 0.061D + 0.042BD + 0.247E - 0.028BDE - 0.050F + 0.025DF + 0.028BDF$$

$$FM_{CpMLR} = 0.503 - 0.041A + 0.076B + 0.058D + 0.038BD + 0.250E - 0.027BDE - 0.041F + 0.033DF$$

$$FM_{MM} = 0.485 - 0.061A + 0.085B + 0.043D + 0.042BD + 0.215E - 0.023BDE - 0.032F + 0.030DF + 0.027BDF$$

The following table includes the main factor coefficient of effects by method for FM values.

FACTORS / METHODS	μ	A	B	C	D	E	F
MSE	.384	-.155	0	0	0	.078	0
Sp	.495	-.101	0	0	0	.178	0
Cp	.487	-.102	0	0	.032	.178	0
Miller's	.433	-.064	.061	0	.042	.173	-.030
MLRMSE	.406	-.078	.063	0	.035	.170	-.032
MLRSp	.416	-.082	.062	0	.040	.187	-.030
MLRCp	.390	-.099	.058	0	.034	.177	-.030
MSEMLR	.443	-.083	.062	0	.031	.170	-.031
SpMLR	.499	-.035	.074	0	.061	.247	-.050
CpMLR	.503	-.041	.076	0	.058	.250	-.041
MM	.485	-.061	.085	0	.043	.215	-.032

Table 5-3.

Summery table of FM values of the effects of the main factors.

Results of FM Measurement

1. Intercept(μ)

The highest mean FM value was calculated for CpMLR Method (0.503). This method was followed with very small difference by FM value calculated for SpMLR method. The MM Method has the fifth large FM value, but the difference between the first and fifth one is not too large.

2. Factor A (Number of Extraneous Variables)

All methods are influenced by the number of extraneous variables. The least influenced one is SpMLR (-0.035) and the most influenced method is MSE (-0.155). The MM Method is the third least influenced method (-0.061).

3. Factor B (Correlation of Independent Variables)

Only MSE, Sp and Cp methods are not influenced by this factor. The most affected one is the MM Method (0.085).

4. Factor C (Variance of the Extraneous Variables)

None of the methods are influenced by this factor.

5. Factor D (Variance of Independent Variables)

All methods, except MSE and Sp are influenced by this factor. The most affected one is SpMLR Method (0.061)

6. Factor E (Sample Size)

All methods are influenced by this factor and it is the dominant one. The most affected method is CpMLR (o.250) and MM Method is the third most affected with coefficient 0.215.

7. Factor F (Error Term)

All methods are influenced by the Error Term except MSE, Sp and Cp methods. The most influenced one is SpMLR Method.

Analysis Based on Mean and Standard Deviation of PM and FM Values

In order to get better insight of the performance of the examined methods the mean and the standard deviation of their PM and FM values are calculated, and the results are given in the table 5-4.

	PM Values		FM Values	
	Mean	St.Dev.	Mean	St.Dev.
Min. MSE	0.7790	0.0985	0.3840	0.1894
Min. Sp	0.8500	0.0772	0.4940	0.2277
Min. Cp	0.8430	0.0765	0.4857	0.2260
Miller's	0.8770	0.0526	0.4320	0.2176
MLRMSE	0.8908	0.0694	0.4059	0.2242
MLRSp	0.8948	0.1205	0.4158	0.2418
MLRCp	0.8820	0.0767	0.3903	0.2381
MSEMLR	0.8733	0.0664	0.4425	0.2219
SpMLR	0.9517	0.0441	0.4992	0.2891
CpMLR	0.9513	0.0432	0.5033	0.2921
MM Mth.	0.9286	0.0391	0.4849	0.2618

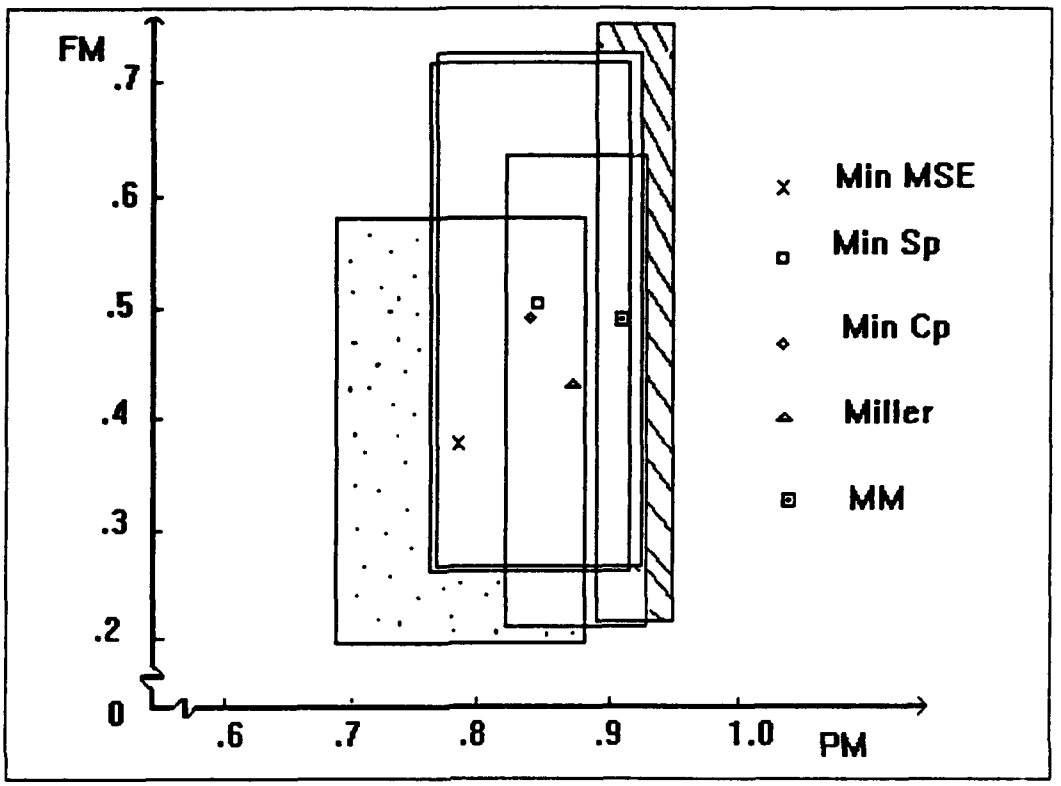
Table 5-4.

The mean and standard deviation of PM and FM value of the employed subset selection technique.

In order to have clear and understandable graphs, the analysis of the methods according to their PM and FM mean value and standard deviation is performed in four steps. The width of the boxes drown in the following graphs represent the standard deviation of the PM values, and the height of the boxes represent the standard deviation of the FM values. The character in the center of a box represents the mean value of the performance measurements of the studied technique. For example the mean PM value of Minimum MSE method displayed in Table 5-4 is 0.7790 and mean FM value is 0.3840. It is displayed in (0.7790,0.3840) coordinates of PM-FM plane as x. Standard deviation of PM value is displayed as a horizontal line beginning from 0.7790-0.0985=0.6805 and ending at 0.7790+0.0985=0.8775. The same way the vertical line was computed, which demonstrates the one standard deviation from the mean in FM values.

Step 1: Analysis of one step subset selection method

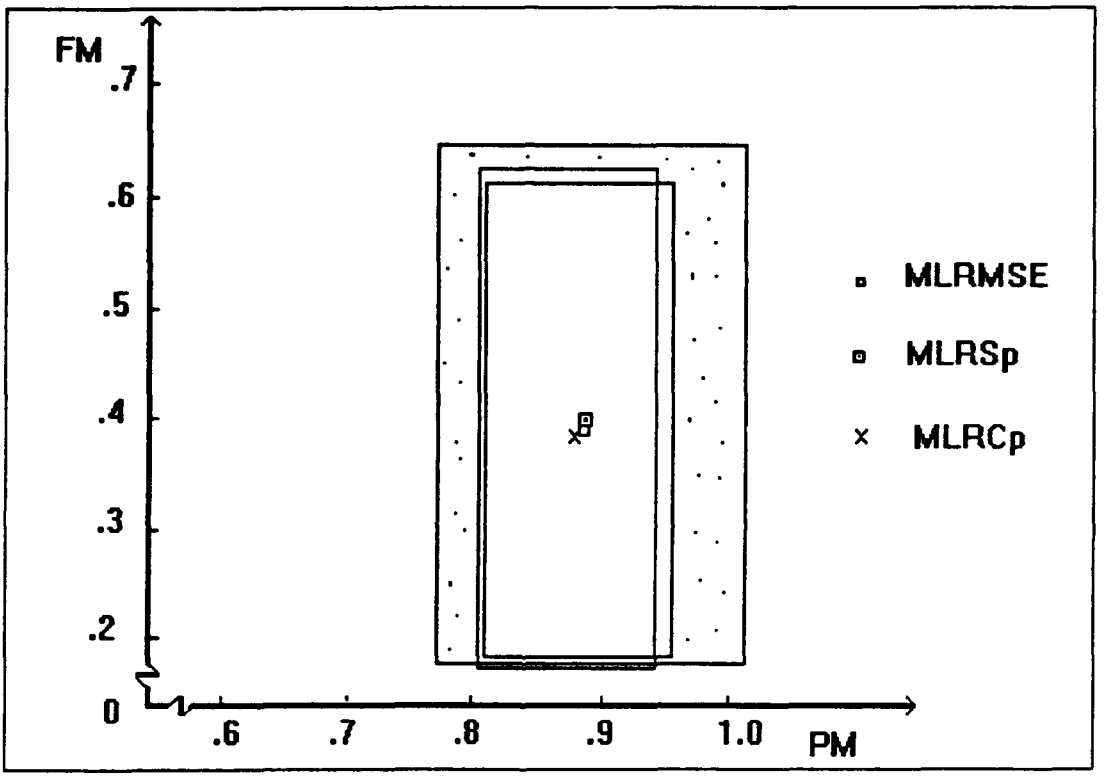
This analysis considers Minimum MSE, Minimum Sp, Minimum Cp, Miller's method and the MM method. The results are displayed in Graph 5-1.



Graph 5-1.

Considering PM measurement it is observed that MM method performs much better than other methods, since it has the largest mean and the smallest standard deviation. Considering the FM measurements of Sp, MM and Cp methods one can tell that they have almost the same mean value. The variance of MM method is higher than the others. But considering the two measurements together, MM method looks as the best one. For the tradeoff having large variance in FM measurement it performs wonderful in PM measurement.

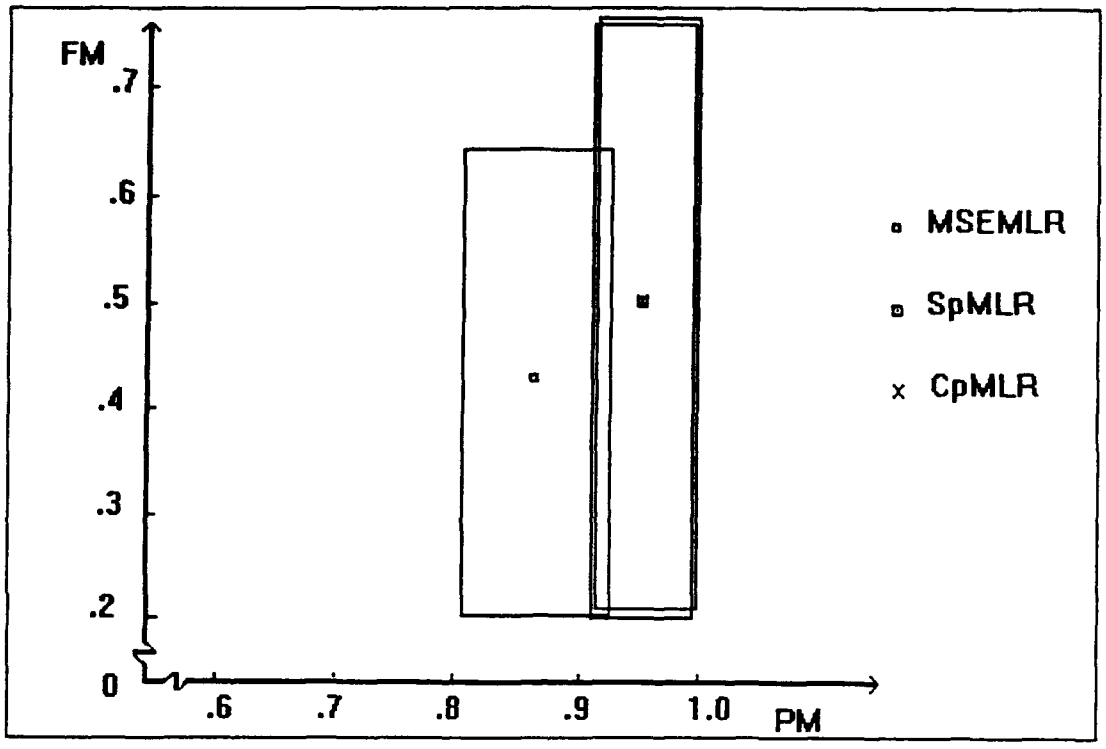
Step 2: Analysis of two stage subset selection methods, where Miller's method is used for screening. This analysis is displayed in Graph 5-2.



Graph 5-2.

Considering both performance measurements, none of the methods perform clearly better than the others. But MLRMSE method can be selected as the best one since it has the smallest standard deviation.

Step 3: Analysis of two stage subset selection methods, where Miller's method is used for final model selection. Analysis is displayed in Graph 5-3.

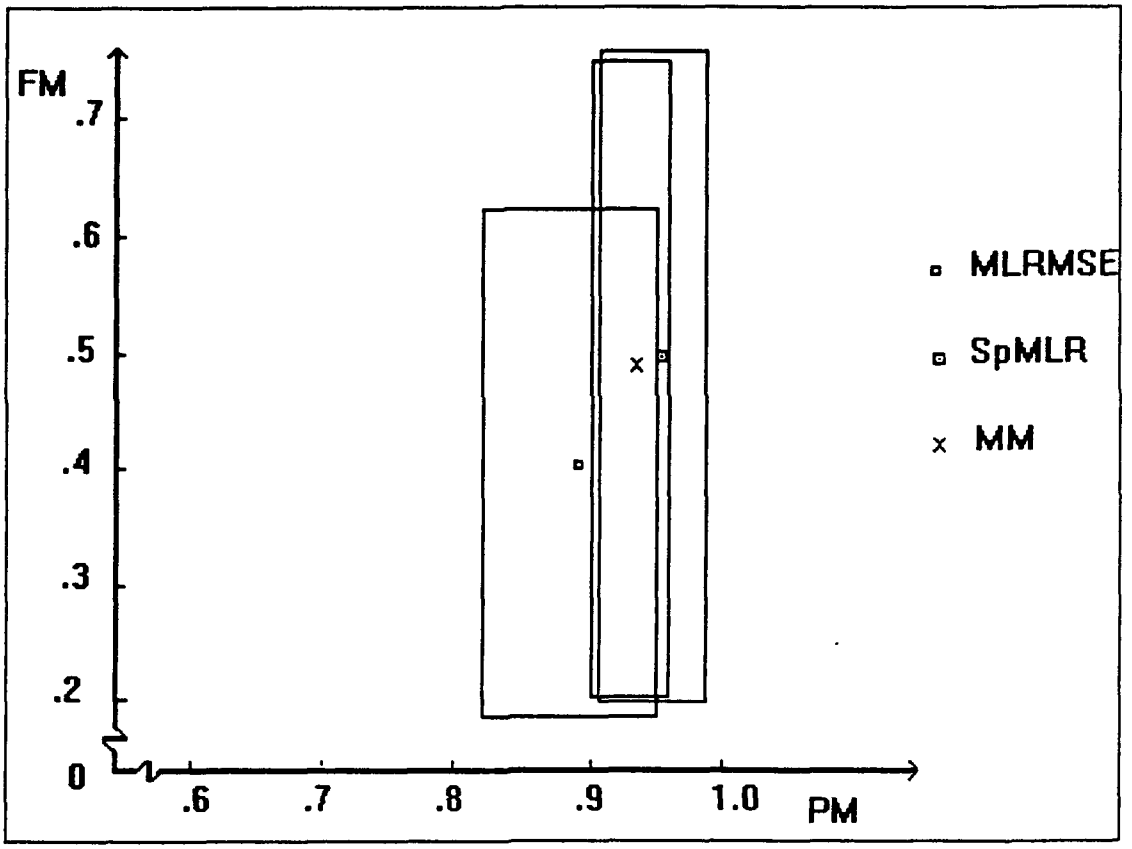


Graph 5-3.

It is observed that SpMLR and CpMLR methods performed almost the same and are each better then the MSEMLR method. So, for the comparison in the step 4 either of them can be selected, let's say SpMLR method.

Step 4: Search for the best of the best subset selection methods.

In this analysis the methods which are considered the best in the previous three steps are compared. The analysis is displayed in Graph 5-4.



Graph 5-4.

According to this final graph SpMLR method (CpMLR is equivalent) performs the best. The mean values of SpMLR method is little bit higher than the mean of the MM method, but the standard deviation of MM method is slightly smaller than the standard deviation of SpMLR method. Because MM method is a one stage method and is not considering all-possible subsets, for larger pool of variables it could be preferable to the SpMLR method, which would require much computational time and effort.

VI. Conclusion and Recommendations For Further Research

Conclusion

Objective. The objectives of this thesis research were: (1) introduce and study a modification of Miller's method which we call the modified Miller's method (MM method), (2) study two step subset selection procedures, one of which applies Miller's method in the first step and employs Minimum MSE or Minimum Sp or Minimum Cp in the second step and other of which employs Minimum MSE or Minimum Sp or Minimum Cp in the first step and applies Miller's Method in the second step. (3) Compare the results of all techniques, including the results of methods studied by Hansen in 1988 and Woollard in 1993 (Minimum MSE, Minimum Sp, Minimum Cp and Miller's method).

Techniques Studied. Techniques studied in this research: (1) Applying Miller's method in the first step for screening and Minimum MSE or Minimum Sp or Minimum Cp in

the second step. These techniques were named MLRMSE, MLRSp and MLRCp, (2) Applying Minimum MSE or Minimum SP or Minimum Cp in the first step and Miller's method in the second step. These technique were named MSEMLR, SpMLR and CpMLR, and, (3) Modified-Miller's Method (MM method) was implemented for the subset selection.

Methodology. In the two stage subset selection method applied in this research, essentially two approaches have been used. In the first one Miller's method was employed for screening and Minimum MSE, or Minimum Sp or Minimum Cp was used for final model selections. In the second approach data were screened by Minimum MSE or Minimum Sp or Minimum Cp and Miller's method was used for final model selection. Modifications were done in Miller's method by augmenting the variable pool with known extraneous variables where the number of known extraneous variables was based upon sample size of the original data, and multiple runs were done where the data of original variables are fixed and the data of known extraneous variables are changed for each run. This new procedure was named Modified-Miller's method (MM method). For the evaluation of the performance of each method two performance measurements were employed. The first one called performance Measurement(PM), measured the

percentage of correct variables in a model. The second measurement called Full Model (FM) measured the percentage of the number of models consisting of {X1 X2 X3} to the number of all models generated.

Response surface methodology was employed to observe the influence of statistical characteristics of the data to the performance of each method. It is observed that for PM measurement SpMLR method has the highest mean value (0.952) and CpMLR method is second with mean 0.951. The MM method performed the third best with mean value 0.929. The worst performing method is Minimum MSE method with mean 0.780. MLRSp method was not influenced by any of the factors, and factor C (variance of extraneous variables) has no influence on any method. The factor A (Number of extraneous variables) is one of the domain factors. The most influence it has is upon Minimum MSE method with coefficient -0.100 and the small influence upon SpMLR CpMLR and MM method with coefficient -0.021 for all. The other domain factor is Sample size (factor E). The most influenced method is MM method with value 0.024 and MLRMSE, MLRSp and MLRCp method were not influenced by this factor. Thus, considering these influence of the characteristics of the data, SpMLR, CpMLR and MM method can be used for screening the extraneous variables and their performance can be

increased with the increased sample size. If there is not much insight about the characteristics of the data on hand, the MLRSp method can be employed for screening the variables with the tradeoff having less mean performance value. In terms of finding the right number of real predictors, FM measurement indicates that CpMLR and SpMLR performs the best with mean values 0.503 and 0.499 respectively. The worst performing method is Minimum MSE with mean (0.384). The MM method performed fairly good with mean 0.485. The sample size (factor E) is the domain factor for getting better results. The most influenced methods by this factor are CpMLR, SpMLR and MM methods (0.250, 0.247 and 0.215 respectively). Therefor, if increasing the sample size is easily possible employing one of these methods will provide better results for finding the right number of real predictors.

For the evaluation of the influence of factors considering both PM and FM measurement, mean values and their standard deviations were computed. In terms of the mean values and standard deviation criteria it is observed that SpMLR and CpMLR methods performing the best. The MM method is the next one with a very small difference. It should be considered that in this thesis research because of the computer allocation problems MM method is applied with 6

runs, which is smaller than what was recommended. In order to observe the influence of this limitation 8 random set of data including 3 extraneous were selected and MM method was employed with run=60. The comparative results of having six runs and having sixty runs were given in the Table 6-1.

Des.Pnt.-Data Set	60 Replications	6 Replications
06-03	X3 X1 X2	X3 X1 X2
06-08	X2 X3 X1	X2 X3 X1
34-03	X1	X1 E2 X2 E1
40-03	X1 X2	X1 X2
46-26	X1 E3 E1	X1 E3 E1
50-53	X2	X2
54-03	X2 E3	X2 E3
60-10	X2 X1 X3	X2 X1 X3
PM Value	0.854	0.791
FM Value	0.375	0.375

Table 6-1.

In the Table 6-1 the rows are labeled with the design point and data set, columns are labeled with the number of runs.

According to the results of Table 6-1, the only difference is observed for the results of design point 34 and set 3, therefor, having six runs is not a bad choice but having sixty runs provides better results.

Considering the results of Table 6-1, the MM method is expected to perform better if it were applied with the recommended run numbers. Therefor, it would be hard to tell that CpMLR or SpMLR performs better than MM method. One other reason to favor the MM method is its having a smaller standard deviation. The last and the most important reason to consider the MM method as the best one is the application of either the CpMLR or the SpMLR methods is hard for a variable pool of large size.

Recommendations For Further Research

This research can address the following further researches:

1. To expand the number of factors under consideration.

To test the behavior and the performance of the methods compared in this research to different statistical

characteristics not included in this research such as negative correlation, larger sample size and variance, may give better insight of the phenomena. The researcher should be warned that he could have computer allocation problems. To eliminate that problem he could reduce number of sets from 60 to, stay 30.

2. Running MM method for large run number.

It will be easy to run MM method for large number of replication, say 30. This results can be compared with the results of methods studied in this thesis.

3. Applying MM method to a large set.

Applying MM method to a pool of variables where the number of variables is large, say 25. An embellishment of this could be applying MM method 5 times to 5 different combination of 5 variables chosen from variable pool of size 25.

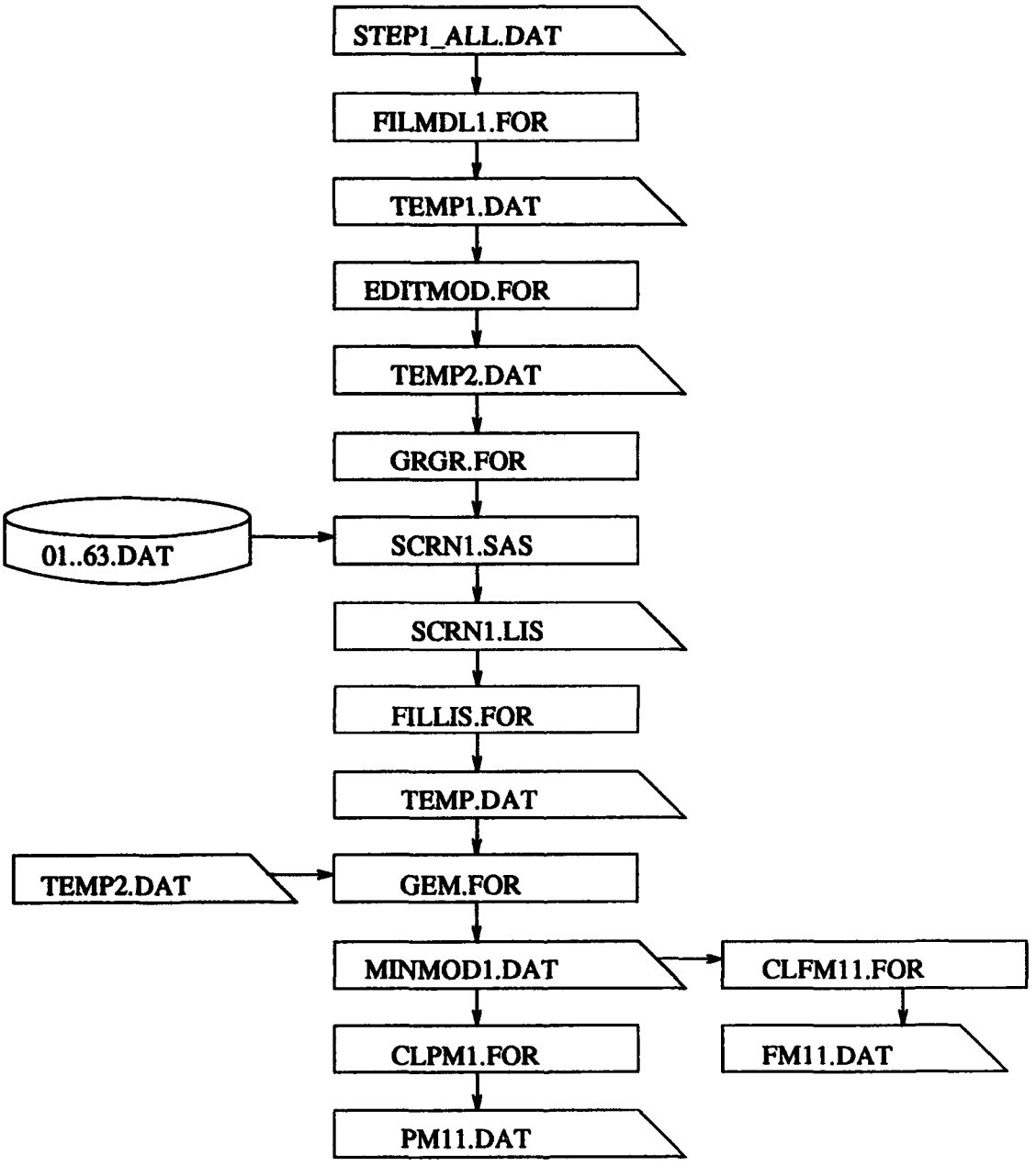
Definition of Flow Chart Symbols

represents FORTRAN and SAS codes

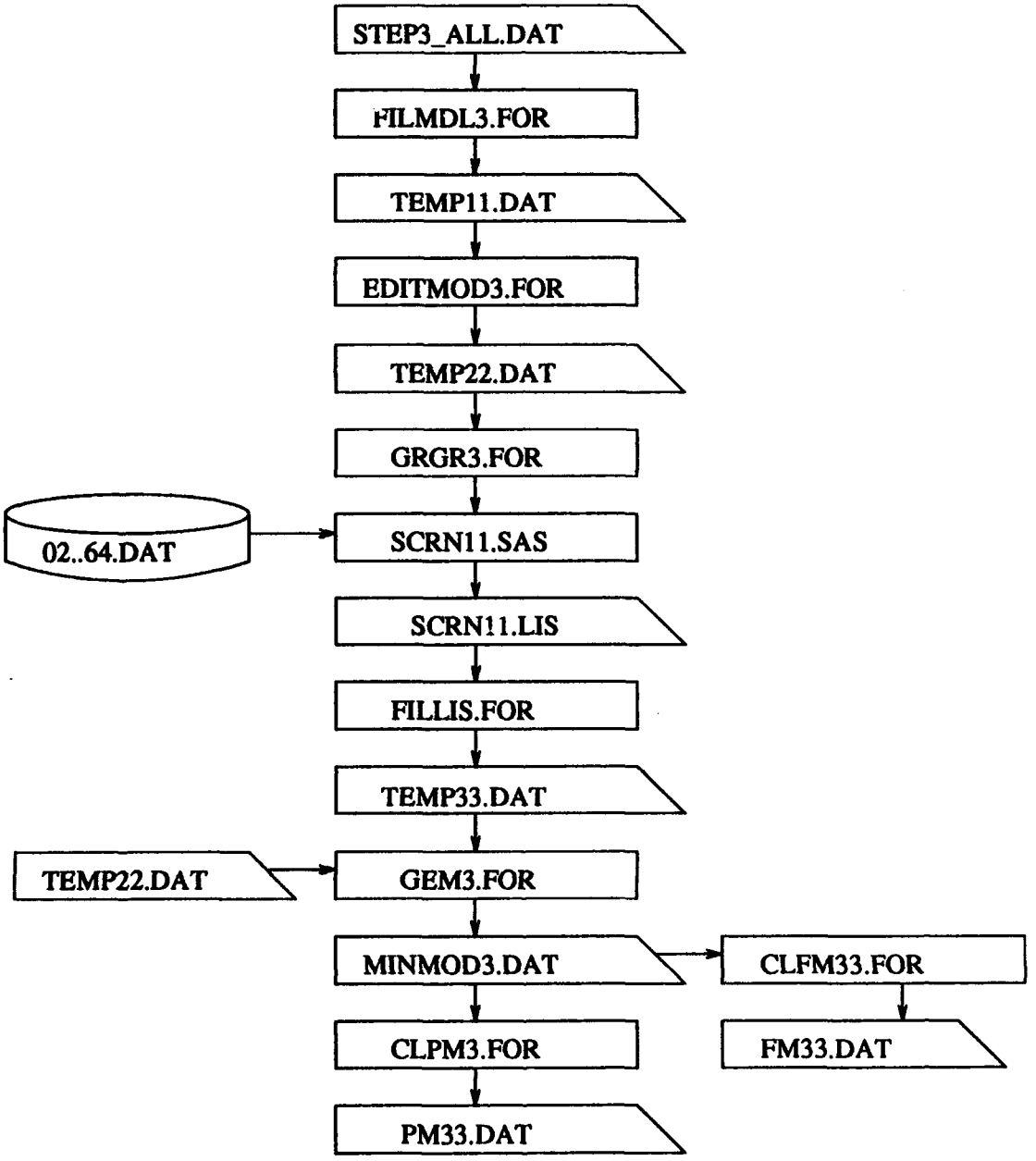
represents FORTRAN *.dat files and SAS *.lis files

represents the generated data files

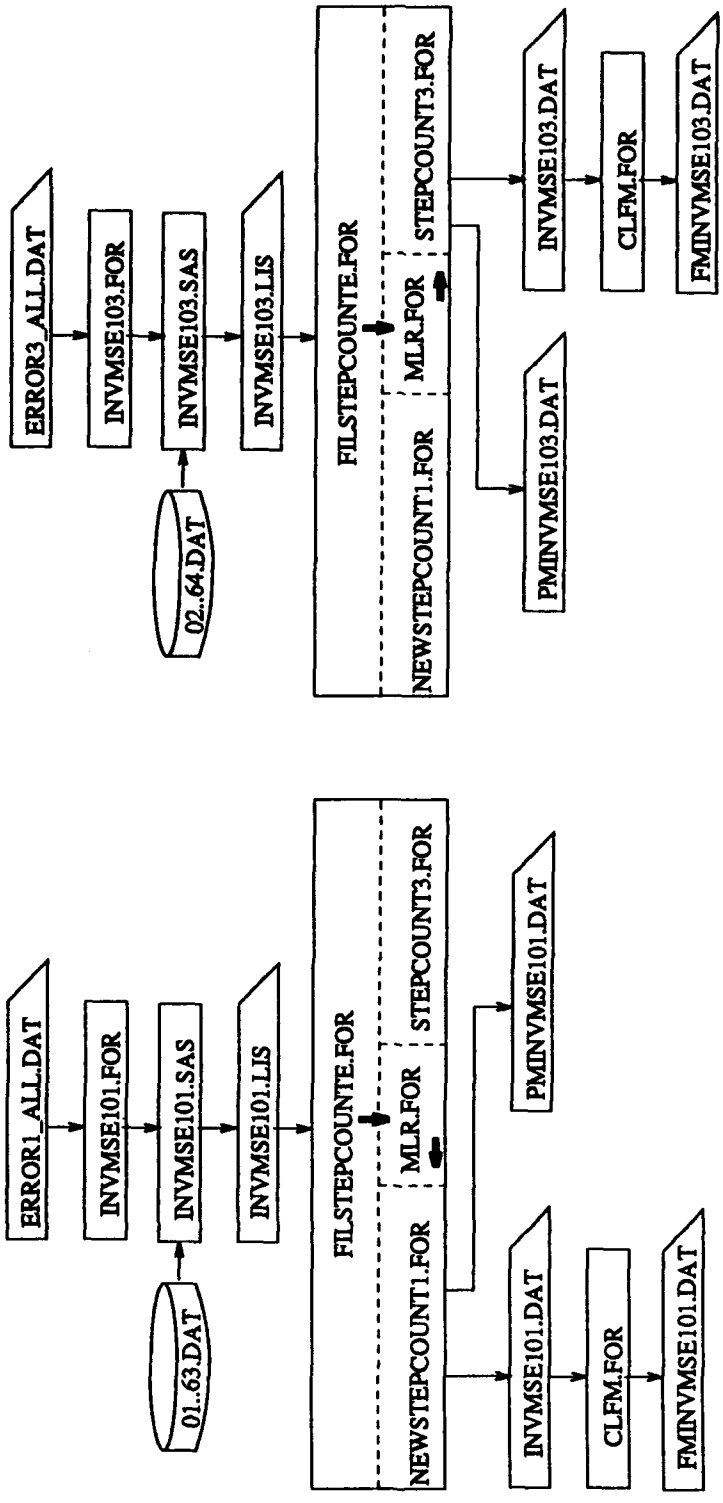
APPENDIX A : Flow chart for two stage subset selection where Miller's method is used for screening (1 extraneous variable)



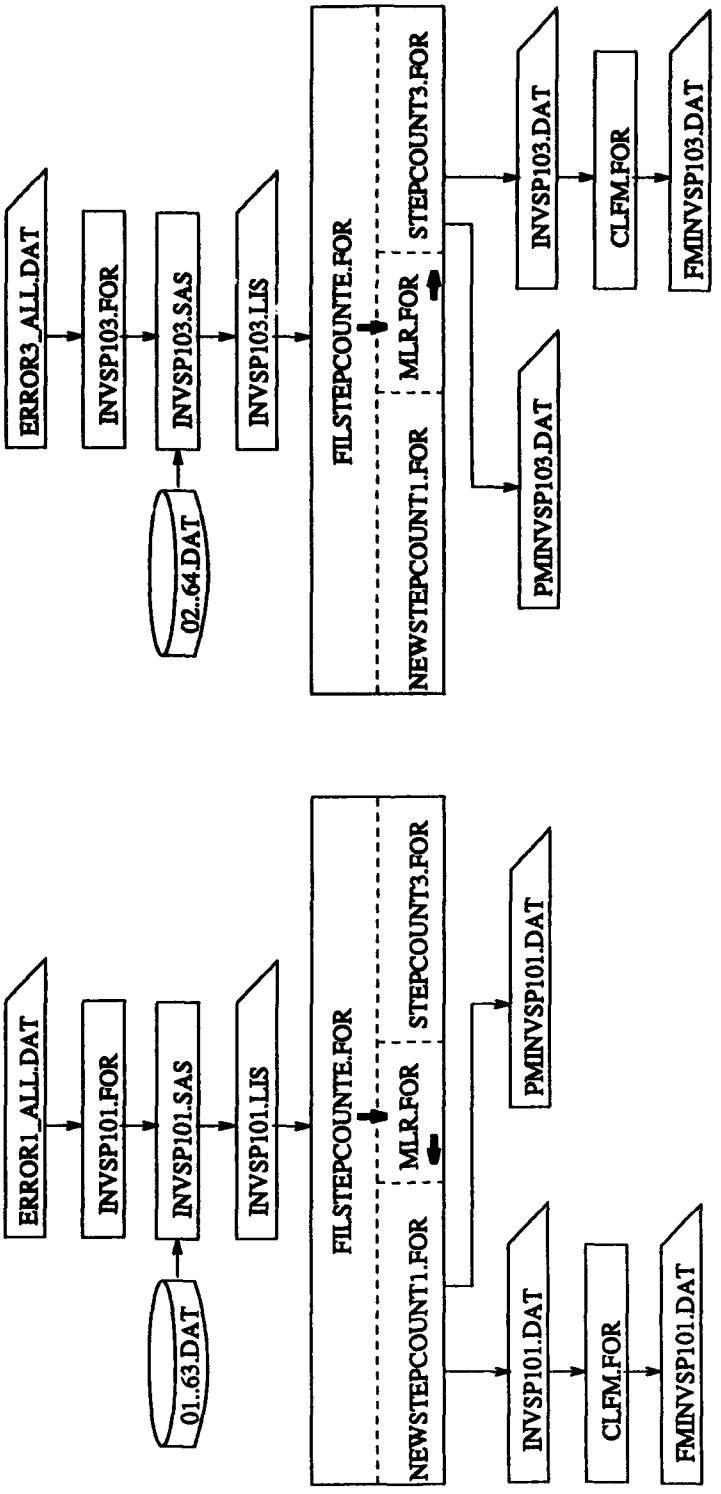
APPENDIX B : Flow chart for two stage subset selection where Miller's method is used for screening (3 extraneous variable)



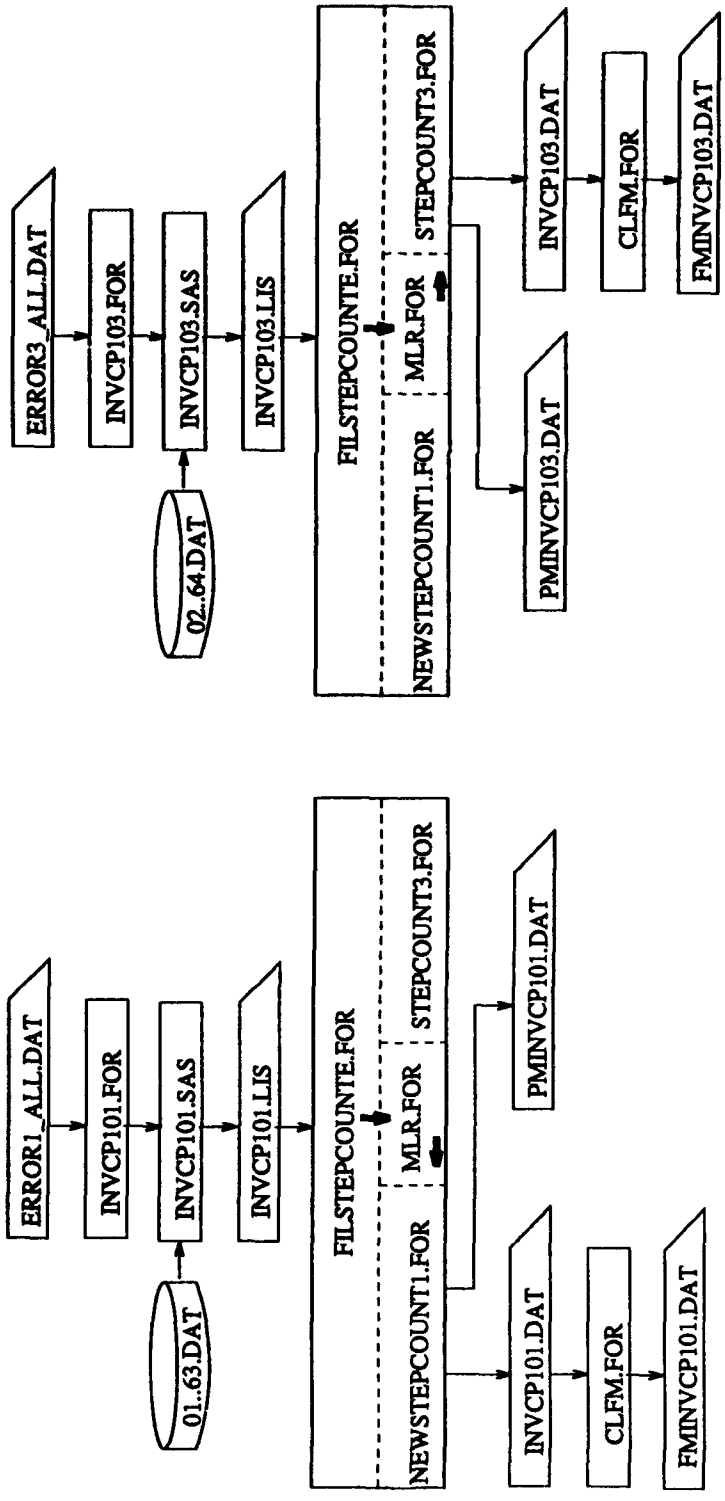
APPENDIX C : Flow chart for two stage subset selection where Minimum MSE is used for screening and Miller's method is used for final model selection



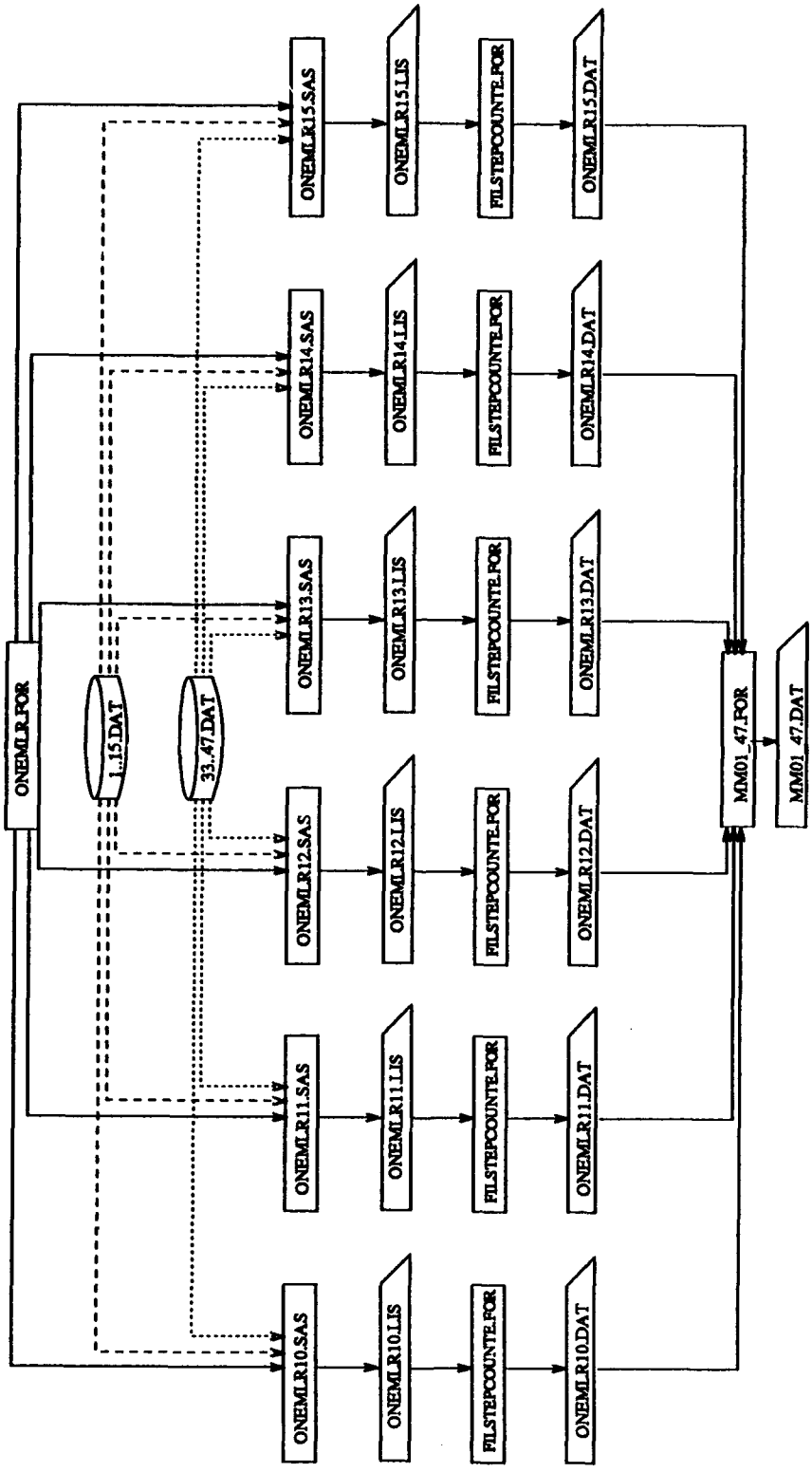
APPENDIX D : Flow chart for two stage subset selection where Minimum Sp is used for screening and Miller's method is used for final model selection



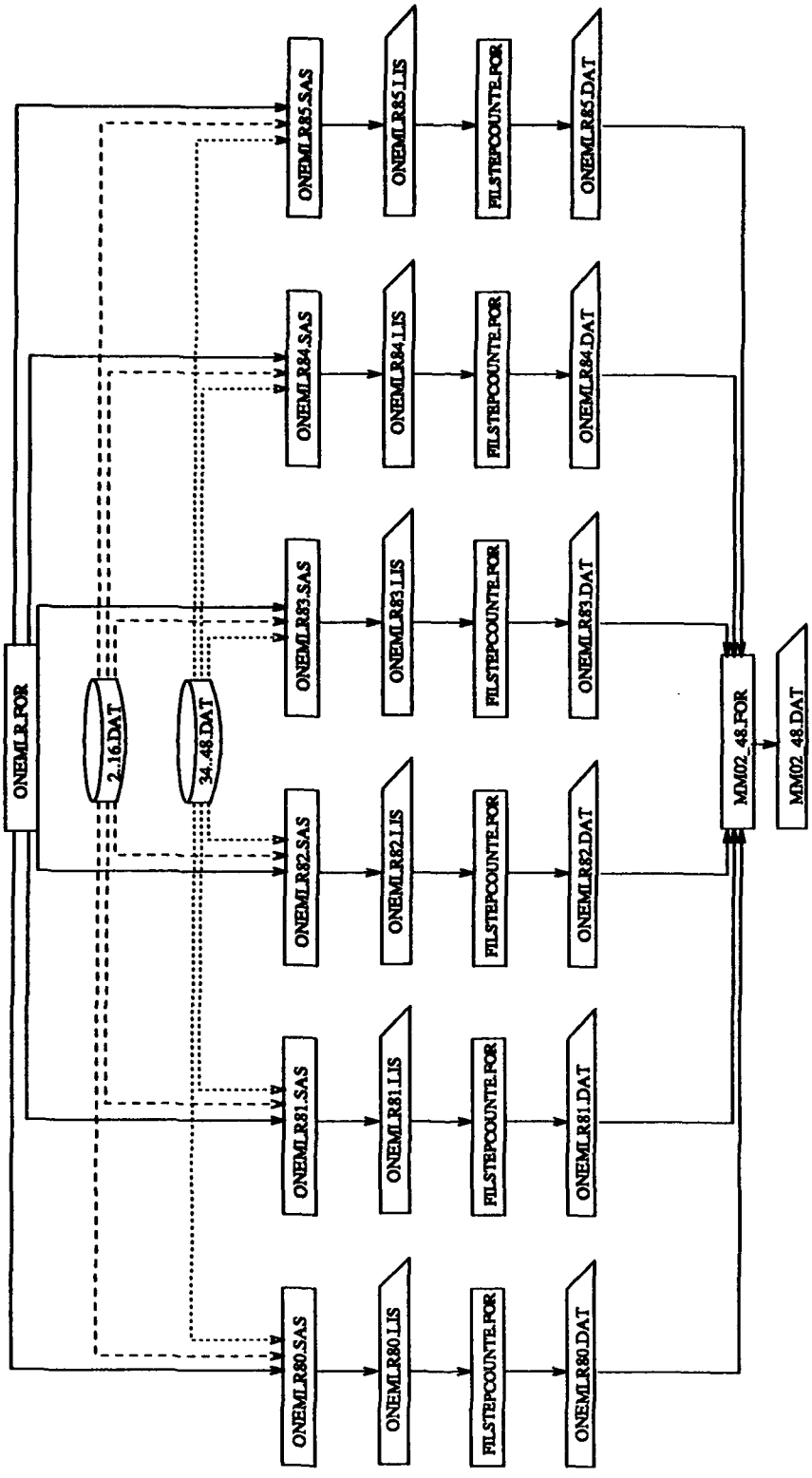
APPENDIX E : Flow chart for two stage subset selection where Minimum Cp is used for screening and Miller's method is used for final model selection



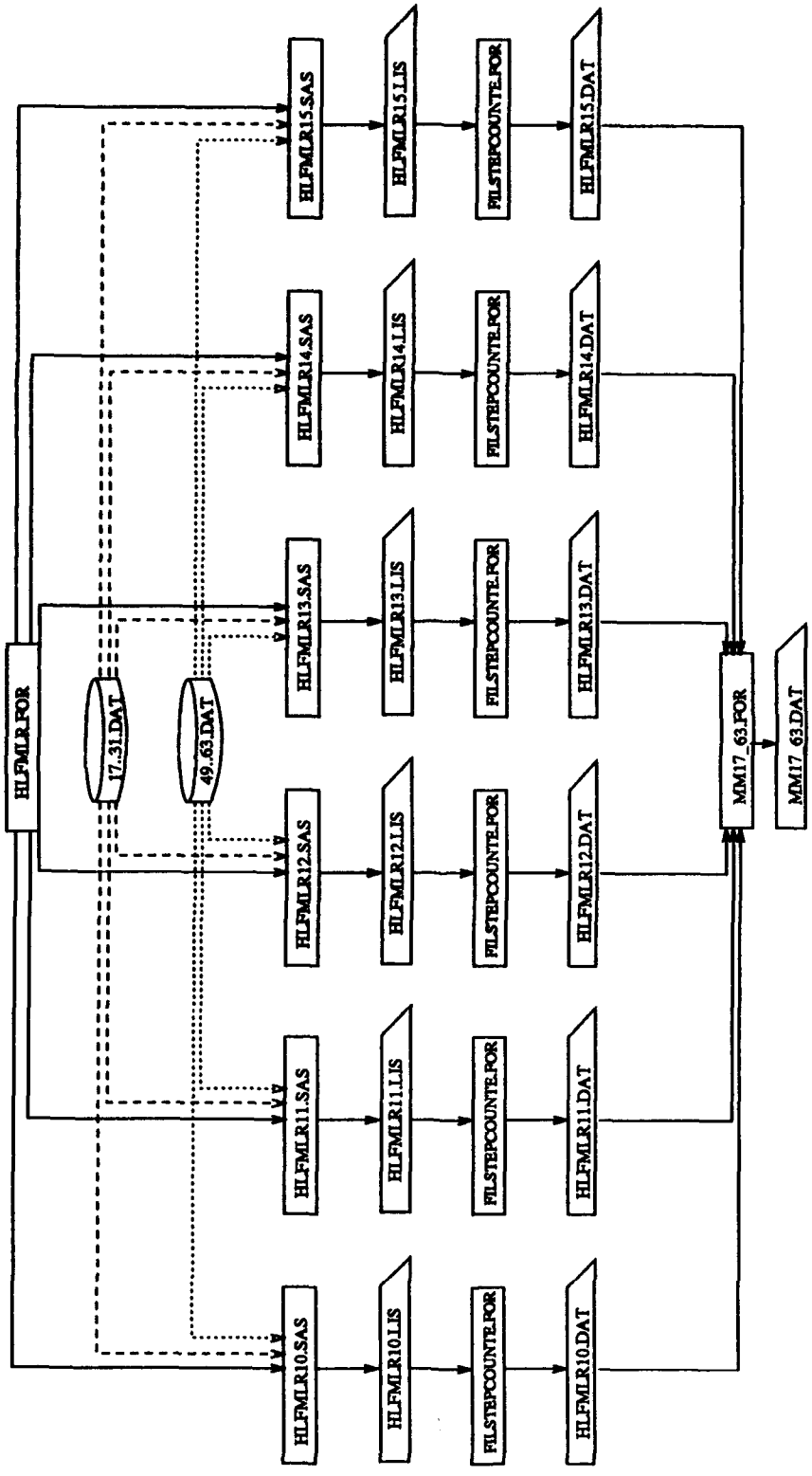
APPENDIX F : Flow chart for MM method for sample size 10 and 1 extraneous



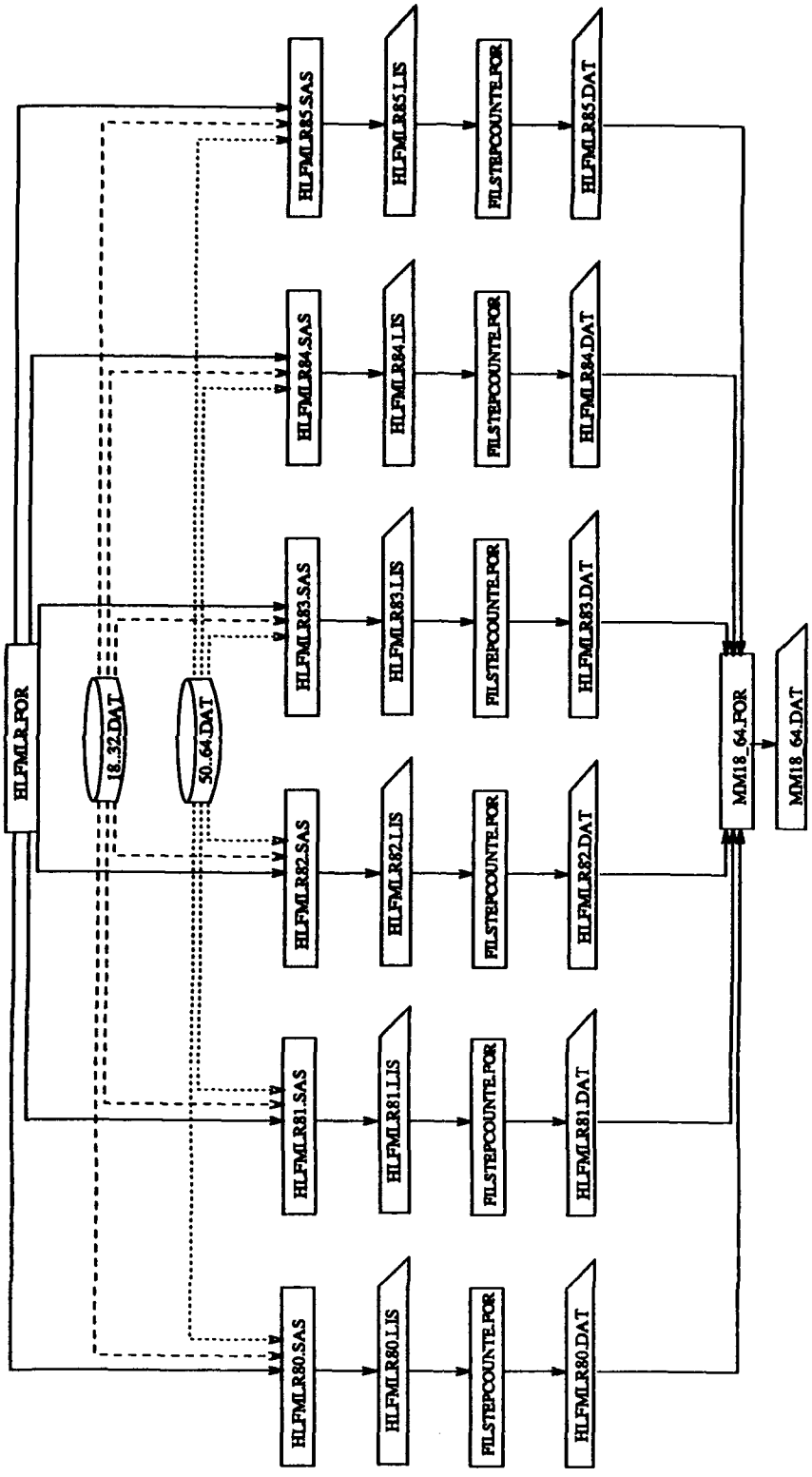
APPENDIX G : Flow chart for MM method for sample size 10 and 3 extraneous



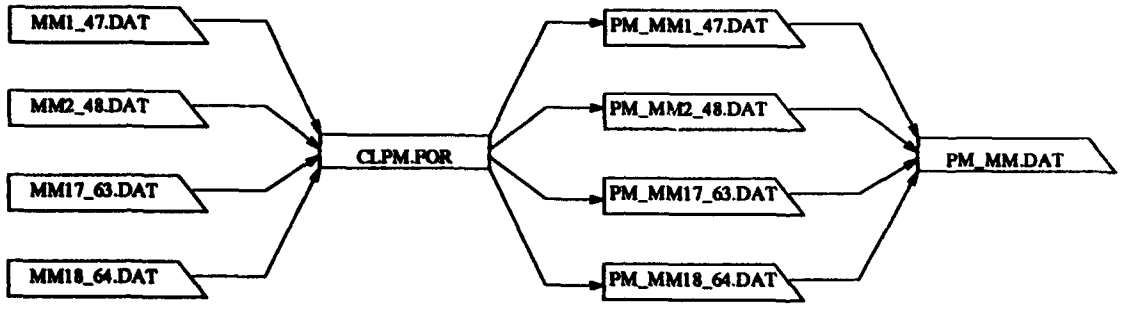
APPENDIX H : Flow chart for MM method for sample size 20 and 1 extraneous

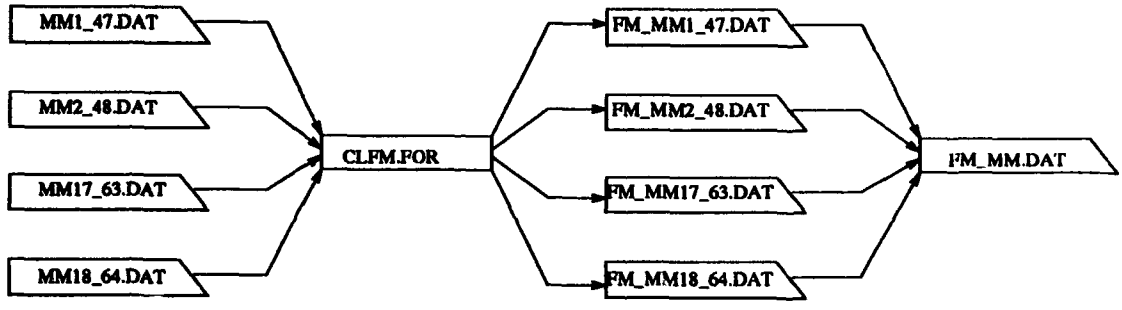


APPENDIX I : Flow chart for MM method for sample size 20 and 3 extraneous

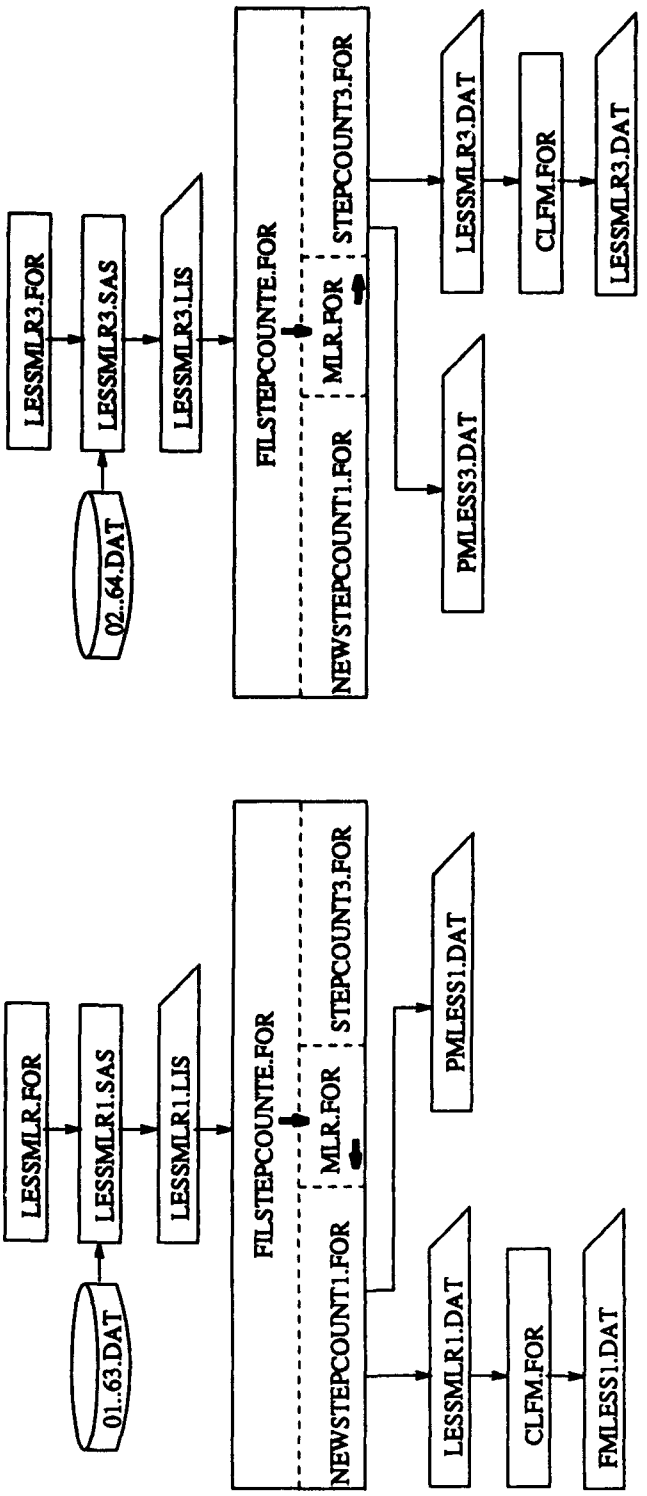


APPENDIX J : Combining different data files and finding PM and FM value for all design points





APPENDIX K : Flow chart for Miller's method with augmentation coefficient 0.5



Note : For coefficients 1, 1.5 and 2 change "LESS" to "ONE", "HLF" and "DBL" repectively

Appendix L: FORTRAN Programs

```
************************** CLFM11.FOR  ***********************

      character*80 line
      character*3 t
      character*11 m
      open(unit=1,file='minmod1.dat',status='old')
      open (unit=2,file='fm11.dat',status='new')
      do 10 k=1,63,2
      fmmse=0
      fmsp=0
      fmcp=0
      do 20 j=1,180
      read (1,500,end=200) line
      t= line(2:4)
      m= line(62:72)
      IF (t.EQ.'MSE') goto 15
      IF (t.EQ.'Sp ') goto 25
      IF (t.EQ.'Cp ') goto 35

15    IF((m.EQ.'X1 X2 X3   ').OR.(m.EQ.'X1 X3 X2   '))
     +fmmse=fmmse+1
      IF((m.EQ.'X3 X1 X2   ').OR.(m.EQ.'X3 X2 X1   '))
     +fmmse=fmmse+1
      IF((m.EQ.'X2 X1 X3   ').OR.(m.EQ.'X2 X3 X1   '))
     +fmmse=fmmse+1
      goto 20

25    IF((m.EQ.'X1 X2 X3   ').OR.(m.EQ.'X1 X3 X2   ')) fmsp=fmsp+1
      IF((m.EQ.'X3 X1 X2   ').OR.(m.EQ.'X3 X2 X1   ')) fmsp=fmsp+1
      IF((m.EQ.'X2 X1 X3   ').OR.(m.EQ.'X2 X3 X1   ')) fmsp=fmsp+1
      goto 20

35    IF((m.EQ.'X1 X2 X3   ').OR.(m.EQ.'X1 X3 X2   ')) fmcp=fmcp+1
      IF((m.EQ.'X3 X1 X2   ').OR.(m.EQ.'X3 X2 X1   ')) fmcp=fmcp+1
      IF((m.EQ.'X2 X1 X3    ').OR.(m.EQ.'X2 X3 X1    '))
     +fmcp=fmcp+1

20    CONTINUE
      vmse=fmmse/60
      vsp=fmsp/60
      vcp=fmcp/60
      write(2,*) k, vmse ,vsp, vcp
10    continue
500   format(A80)
200   stop
      end
```

```
********************** CLFM33.FOR **********************

      character*80 line
      character*3 t
      character*11 m
      open(unit=1,file='minmod3.dat',status='old')
      open (unit=2,file='fm33.dat',status='new')
      do 10 k=2,64,2
      fmmse=0
      fmsp=0
      fmcp=0
      do 20 j=1,180
      read (1,500,end=200) line
      t= line(2:4)
      m= line(62:72)
      IF (t.EQ.'MSE') goto 15
      IF (t.EQ.'Sp ') goto 25
      IF (t.EQ.'Cp ') goto 35

15    IF((m.EQ.'X1 X2 X3   ').OR.(m.EQ.'X1 X3 X2   '))
     +fmmse=fmmse+1
      IF((m.EQ.'X3 X1 X2   ').OR.(m.EQ.'X3 X2 X1   '))
     +fmmse=fmmse+1
      IF((m.EQ.'X2 X1 X3   ').OR.(m.EQ.'X2 X3 X1   '))
     +fmmse=fmmse+1
      goto 20

25    IF((m.EQ.'X1 X2 X3   ').OR.(m.EQ.'X1 X3 X2   ')) fmsp=fmsp+1
      IF((m.EQ.'X3 X1 X2   ').OR.(m.EQ.'X3 X2 X1   ')) fmsp=fmsp+1
      IF((m.EQ.'X2 X1 X3   ').OR.(m.EQ.'X2 X3 X1   ')) fmsp=fmsp+1
      goto 20

35    IF((m.EQ.'X1 X2 X3   ').OR.(m.EQ.'X1 X3 X2   ')) fmcp=fmcp+1
      IF((m.EQ.'X3 X1 X2   ').OR.(m.EQ.'X3 X2 X1   ')) fmcp=fmcp+1
      IF((m.EQ.'X2 X1 X3   ').OR.(m.EQ.'X2 X3 X1   '))
     +fmcp=fmcp+1

20    CONTINUE
      vmse=fmmse/60
      vsp=fmsp/60
      vcp=fmcp/60
      write(2,*) k, vmse ,vsp, vcp
10    continue
500   format(A80)
200   stop
      end
```

```
************************ CLPM1.FOR ********************************

      real pmmse,pmsp,pmcp
      character*3 mth
      character*2 mod(4)
      integer var,tvarmse,emse,esp,ecp,tvarsp,tvarcp
      open (unit=1,file='minmod1.dat',status='old')
      open (unit=2,file='pm11.dat',status='new')
      do 5 k=1,63,2
        emse=0
        esp=0
        ecp=0
        tvarmse=0
        tvarsp=0
        tvarcp=0
        do 10 I=1,60
          read(1,500,end=200)mth,var,mod(1),mod(2),mod(3),mod(4)
          if (mth.EQ.'MSE') then
            tvarmse=tvarmse+var
            do 20 j=1,4
              if (mod(j).EQ.'E1') then
               emse=emse+1
               endif

20             continue
          else
          if (mth.EQ.'Sp ') then
            tvarsp=tvarsp+var
            do 30 j=1,4
              if (mod(j).EQ.'E1') then
               esp=esp+1
               endif

30             continue
          else
          IF (mth.EQ.'Cp ') then
            tvarcp=tvarcp+var
            do 40 j=1,4
              if (mod(j).EQ.'E1') then
              ecp=ecp+1
              endif

40             continue
           ENDIF
           ENDIF
           ENDIF
```

```
10        continue
          dmse=tvarmse-emse
          dsp= tvarsp-esp
          dcp= tvarcp-ecp
          pmmse= dmse / tvarmse
          pmsp= dsp / tvarsp
          pmcp= dcp / tvarcp
         write (2,*) k,pmmse,pmsp,pmcp
5       continue
500     format (1X,A3,11X,I1,45X,A2,1X,A2,1X,A2,1X,A2)
200     STOP
        END
```

```
************************** CLPM3.FOR ****************************

      real pmmse,pmsp,pmcp
      character*3 mth
      character*2 mod(6)
      integer var,tvarmse,emse,esp,ecp,tvarsp,tvarcp
      open (unit=1,file='minmod3.dat',status='old')
      open (unit=2,file='pm33.dat',status='new')
      do 5 k=2,64,2
        emse=0
        esp=0
        ecp=0
        tvarmse=0
        tvarsp=0
        tvarcp=0
        do 10 I=1,60
     read(1,500,end=200)
     + mth,var,mod(1),mod(2),mod(3),mod(4),mod(5),mod(6)
            IF (mth.EQ.'MSE') then
              tvarmse=tvarmse+var
              do 20 j=1,6
      if((mod(j).EQ.'E1').OR.(mod(j).EQ.'E2')
     +.OR.(mod(j).EQ.'E3'))then
                  emse=emse+1
                  endif

20    continue
            else
            IF (mth.EQ.'Sp ') then
              tvarsp=tvarsp+var
              do 30 j=1,6

      if((mod(j).EQ.'E1').OR.(mod(j).EQ.'E2')
     + .OR.(mod(j).EQ.'E3')) then
                  esp=esp+1
                  endif

30               continue
            else
            IF (mth.EQ.'Cp ') then
              tvarcp=tvarcp+var
              do 40 j=1,4
      if ((mod(j).EQ.'E1').OR.(mod(j).EQ.'E2')
     +.OR.(mod(j).EQ.'E3')) then
                 ecp=ecp+1
                 endif
```

```
40              continue
              ENDIF
              ENDIF
              ENDIF

10          continue
            dmse=tvarmse-emse
            dsp= tvarsp-esp
            dcp= tvarcp-ecp
            pmmse= dmse / tvarmse
            pmsp= dsp / tvarsp
            pmcp= dcp / tvarcp
           write (2,*) k,pmmse,pmsp,pmcp

5         continue
500       format (1X,A3,11X,I1,45X,A2,1X,A2,1X,A2,1X,A2)
200       STOP
          END
```

```
********** EDITMOD.FOR **********

      INTEGER REP ,VAR
      CHARACTER*12 MOD
      OPEN (UNIT=1,FILE='TEMP1.DAT',STATUS='UNKNOWN')
      OPEN (UNIT=2,FILE='TEMP2.DAT',STATUS='NEW')
      COUNT=0
      DO 10 K=1,1920
         READ(1,500,END=200) REP, VAR, MOD
         IF (VAR.EQ.0) THEN
         VAR=1
         MOD='x4'
         COUNT=COUNT+1
      ENDIF
      WRITE (2,500) REP, VAR, MOD
10    CONTINUE
500   FORMAT (5X,I2,12X,I1,6X,A12)
      PRINT*,'# OF ZERO MODELS=',COUNT
200   STOP
      END
```

```
************************** EDITMOD3.FOR ************************

      INTEGER REP ,VAR
      CHARACTER*12 MOD
      OPEN (UNIT=1,FILE='TEMP11.DAT',STATUS='UNKNOWN')
      OPEN (UNIT=2,FILE='TEMP22.DAT',STATUS='NEW')
      COUNT=0
      DO 10 K=1,1920
         READ(1,500,END=200) REP, VAR, MOD
         IF (VAR.EQ.0) THEN
         VAR=1
         MOD='x4'
         COUNT=COUNT+1
      ENDIF
      WRITE (2,500) REP, VAR, MOD
10    CONTINUE
500   FORMAT (5X,I2,12X,I1,6X,A12)
      PRINT*,'# OF ZERO MODELS=',COUNT
200   STOP
      END
```

```
********************** FILLIS.FOR **************************

      Character*20 NewIn
      Character*20 NewOut
      Character*80 Line
      CHARACTER  I, J
      Integer Var
      Logical VarFlag

5     Continue
      Print *,'Name of file to examine? (20 char or less;',
     +        ' "*" to quit)'
      Read (*,'(A20)') NewIn
      If (NewIn(1:1).EQ.'*') GO TO 999
      Print *,'Output file? (20 char or less)'
      Read (*,'(A20)') NewOut
7     Continue
       Print *,'Number of extraneous variables?(1 or 3
     +ONLY!!)'
      Read (*, '(I1)') Var
      If ((Var.NE.1).AND.(Var.NE.3)) GO TO 7

9     Continue
      VarFlag = (Var.EQ.3)

      Open (unit=10, file=NewIn, status='OLD',
     &      iostat=IERROR, err=1000)

      Open (unit=11, file='temp.dat', status='NEW',
     &      iostat=IERROR, err=1000)
      open (unit=12, file='temp33.dat', status='NEW',
     &      iostat=IERROR, err=1000)

10    Continue
      Read(10,200,END=888) Line
      I = LINE (8:8)
      J = LINE (9:11)

      IF (VarFlag) GO TO 777
      IF ((I.EQ.'1').AND.(J.EQ.'    ')) THEN
        WRITE (11,200) LINE
      ELSE

     IF ((I.EQ.'2').AND.(J.EQ.'    ')) THEN
        WRITE (11,200) LINE
     ELSE

     IF ((I.EQ.'3').AND.(J.EQ.'    ')) THEN
        WRITE (11,200) LINE
```

```
      ELSE

       IF ((I.EQ.'4').AND.(J.EQ.'    ')) THEN
          WRITE (11,200) LINE

             ENDIF
           ENDIF
         ENDIF
        ENDIF

       GO TO 10

777    Continue
       IF ((I.EQ.'1').AND.(J.EQ.'    ')) THEN
          WRITE (12,200) LINE
       ELSE

         IF ((I.EQ.'2').AND.(J.EQ.'    ')) THEN
            WRITE (12,200) LINE
         ELSE

           IF ((I.EQ.'3').AND.(J.EQ.'    ')) THEN
              WRITE (12,200) LINE
           ELSE

             IF ((I.EQ.'4').AND.(J.EQ.'    ')) THEN
                WRITE (12,200) LINE
             ELSE

               IF ((I.EQ.'5').AND.(J.EQ.'    ')) THEN
                  WRITE (12,200) LINE
               ELSE

                 IF ((I.EQ.'6').AND.(J.EQ.'    ')) THEN
                    WRITE (12,200) LINE
                 ENDIF
               ENDIF
             ENDIF
           ENDIF
         ENDIF
        ENDIF

       GO TO 10


200    Format (A80)
888    Continue

       GO TO 5

999    Continue
```

```
      Print *,'Processing complete. Program terminated.'
      Stop

* Error trap: ********************************************
1000  Continue
      Print 1100, '+++ ERROR WHILE OPENING FILE +++',
     &            '       error code = ', IERROR
1100  FORMAT(/1X, A/ 1X, A, I8/)
      GO TO 5
*************************************************************
      END
```

```
********** FILMDL1.FOR **********

      Character*20 NewIn
      Character*20 NewOut
      Character*80 Line
      CHARACTER  I, J
      Integer Var
      Logical VarFlag

5     Continue
      Print *,'Name of file to examine? (20 char or less;',
     +        ' "*" to quit)'
      Read (*,'(A20)') NewIn
      If (NewIn(1:1).EQ.'*') GO TO 999
      Print *,'Output file? (20 char or less)'
      Read (*,'(A20)') NewOut
7     Continue
      Print *,'Number of extraneous variables? (1 ONLY!!)'
      Read (*, '(I1)') Var
      If ((Var.NE.1).AND.(Var.NE.3)) GO TO 7

9     Continue
      VarFlag = (Var.EQ.3)

      Open (unit=10, file=NewIn, status='OLD',
     &      iostat=IERROR, err=1000)

      Open (unit=11, file='temp1.dat', status='NEW',
     &      iostat=IERROR, err=1000)

10    Continue
      Read(10,200,END=888) Line
      I = LINE (20:20)
      J = LINE (21:24)

      IF (VarFlag) GO TO 777

      IF ((I.EQ.'0').AND.(J.EQ.'    ')) THEN

        WRITE (11,200) LINE
      ELSE

      IF ((I.EQ.'1').AND.(J.EQ.'    ')) THEN

        WRITE (11,200) LINE
      ELSE
```

```
      IF ((I.EQ.'2').AND.(J.EQ.'    ')) THEN
          WRITE (11,200) LINE
      ELSE

        IF ((I.EQ.'3').AND.(J.EQ.'    ')) THEN
           WRITE (11,200) LINE
        ELSE

          IF ((I.EQ.'4').AND.(J.EQ.'    ')) THEN
             WRITE (11,200) LINE
          ENDIF
         ENDIF
       ENDIF
      ENDIF
    ENDIF

    GO TO 10

777 Continue

    IF ((I.EQ.'0').AND.(J.EQ.'    ')) THEN
        WRITE (11,200) LINE
    IF ((I.EQ.'1').AND.(J.EQ.'    ')) THEN
        WRITE (11,200) LINE
    ELSE

      IF ((I.EQ.'2').AND.(J.EQ.'    ')) THEN
         WRITE (11,200) LINE
      ELSE

        IF ((I.EQ.'3').AND.(J.EQ.'    ')) THEN
            WRITE (11,200) LINE
        ELSE

          IF ((I.EQ.'4').AND.(J.EQ.'    ')) THEN
             WRITE (11,200) LINE
          ELSE

            IF ((I.EQ.'5').AND.(J.EQ.'    ')) THEN
               WRITE (11,200) LINE
            ELSE

              IF ((I.EQ.'6').AND.(J.EQ.'    ')) THEN
                 WRITE (11,200) LINE
              ENDIF
             ENDIF
            ENDIF
           ENDIF
          ENDIF
         ENDIF
```

```
          ENDIF


      GO TO 10

200   Format (A80)

888   Continue
      Close(10)
      Close(11)

      Print *,'Filtering complete on ',NewIn,'. COUNTING
BEGUN.'

      GO TO 5

999   Continue

      Print *,'Processing complete. Program terminated.'
      Stop

* Error trap: ******************************************
1000  Continue
      Print 1100, '+++ ERROR WHILE OPENING FILE +++',
     &            '      error code = ', IERROR
1100  FORMAT(/1X, A/ 1X, A, I8/)
      GO TO 5
************************************************************
      END
```

```
************************** FILMDL3.FOR **********************

      Character*20 NewIn
      Character*20 NewOut
      Character*80 Line
      CHARACTER  I, J
      Integer Var
      Logical VarFlag

5     Continue
      Print *,'Name of file to examine? (20 char or less;',
     +        ' "*" to quit)'
      Read (*,'(A20)') NewIn
      If (NewIn(1:1).EQ.'*') GO TO 999
      Print *,'Output file? (20 char or less)'
      Read (*,'(A20)') NewOut
7     Continue
      Print *,'Number of extraneous variables? (1 ONLY!!)'
      Read (*, '(I1)') Var
      If ((Var.NE.1).AND.(Var.NE.3)) GO TO 7

9     Continue
      VarFlag = (Var.EQ.3)

      Open (unit=10, file=NewIn, status='OLD',
     &      iostat=IERROR, err=1000)

      Open (unit=11, file='temp11.dat', status='NEW',
     &      iostat=IERROR, err=1000)

10    Continue
      Read(10,200,END=888) Line
      I = LINE (20:20)
      J = LINE (21:24)

      IF (VarFlag) GO TO 777

      IF ((I.EQ.'0').AND.(J.EQ.'    ')) THEN

        WRITE (11,200) LINE
      ELSE

      IF ((I.EQ.'1').AND.(J.EQ.'    ')) THEN

        WRITE (11,200) LINE
      ELSE

        IF ((I.EQ.'2').AND.(J.EQ.'    ')) THEN
```

```
          WRITE (11,200) LINE
        ELSE

          IF ((I.EQ.'3').AND.(J.EQ.'    ')) THEN

            WRITE (11,200) LINE
          ELSE

            IF ((I.EQ.'4').AND.(J.EQ.'    ')) THEN

              WRITE (11,200) LINE
            ENDIF
           ENDIF
          ENDIF
         ENDIF
        ENDIF

      GO TO 10

777   Continue

      IF ((I.EQ.'0').AND.(J.EQ.'    ')) THEN

        WRITE (11,200) LINE
      ELSE

      IF ((I.EQ.'1').AND.(J.EQ.'    ')) THEN

        WRITE (11,200) LINE
      ELSE

        IF ((I.EQ.'2').AND.(J.EQ.'    ')) THEN

          WRITE (11,200) LINE
        ELSE

          IF ((I.EQ.'3').AND.(J.EQ.'    ')) THEN

            WRITE (11,200) LINE
          ELSE

            IF ((I.EQ.'4').AND.(J.EQ.'    ')) THEN

              WRITE (11,200) LINE
            ELSE

              IF ((I.EQ.'5').AND.(J.EQ.'    ')) THEN

                WRITE (11,200) LINE
              ELSE

                IF ((I.EQ.'6').AND.(J.EQ.'    ')) THEN
```

```
                    WRITE (11,200) LINE


                  ENDIF
                ENDIF
              ENDIF
            ENDIF
          ENDIF
        ENDIF
      ENDIF

      GO TO 10


200   Format (A80)

888   Continue
      Close(10)
      Close(11)

      Print *,'Filtering complete on ',NewIn,'. COUNTING BEGUN.'

      GO TO 5

999   Continue

      Print *,'Processing complete. Program terminated.'
      Stop

* Error trap: ********************************************
1000  Continue
      Print 1100, '+++ ERROR WHILE OPENING FILE +++',
     &            '       error code = ', IERROR
1100  FORMAT(/1X, A/ 1X, A, I8/)
      GO TO 5
*************************************************************
      END
```

```
********************** FILSTEPCOUNTE.FOR ************************

      Character*14 NewIn
      Character*20 NewOut
      Character*80 Line
      Character*1 I, J
      Character*2 K
      Integer Var
      Logical VarFlag, BatchFlag

5     Continue
      Print *,'Interactive(I) or Batch(B) mode? (I or B only):'
      Read (*,'(A1)')Mode
      IF ((Mode.NE.'I').AND.(Mode.NE.'B')) Go to 5
      BatchFlag=(Mode.EQ.'B')
      IF (BatchFlag) Go to 6
      Print *,'Name of file to examine? (20 char or less;',
     +        ' "*" to quit)'
      Read (*,'(A20)') NewIn
      If (NewIn(1:1).EQ.'*') GO TO 999
6     Continue
      Print *,'Output file? (20 char or less)'
      Read (*,'(A20)') NewOut
7     Continue
      Print *,'Number of extraneous variables? (1 or 3 ONLY!!)'
      Read (*, '(I1)') Var
      If ((Var.NE.1).AND.(Var.NE.3)) GO TO 7

9     Continue
      VarFlag = (Var.EQ.3)

      IF ((VarFlag).AND.(BatchFlag)) THEN
        Open (unit=9, file='Step3_Input.dat', status='OLD',
     +        iostat=IERROR, err=1000)

      ELSE
        IF ((.NOT.VarFlag).AND.(BatchFlag)) THEN
          Open (unit=9, file='newstep1_Input.dat', status='OLD',
     +          iostat=IERROR, err=1000)

        ENDIF
      ENDIF
11    Continue
      IF (BatchFlag) Read(9,'(A10)',END=666) NewIn
      Print *,'Filtering begun on ',NewIn,'.  Filtered data ',
     +        'is being dumped to MLR.DAT.'

      Open (unit=10, file=NewIn, status='OLD',
     &      iostat=IERROR, err=1000)
```

```
      Open (unit=11, file='mlr.dat', status='NEW',
     &      iostat=IERROR, err=1000)

10    Continue
      Read(10,200,END=888) Line
      I = LINE (5:5)
      J = LINE (6:8)
      K = LINE (4:5)

      IF (VarFlag) GO TO 777

      IF ((I.EQ.'1').AND.(J.EQ.'    ')) THEN
        WRITE (11,200) LINE
      ELSE

       IF ((I.EQ.'2').AND.(J.EQ.'    ')) THEN
        WRITE (11,200) LINE
       ELSE

        IF ((I.EQ.'3').AND.(J.EQ.'    ')) THEN
         WRITE (11,200) LINE
        ELSE

         IF ((I.EQ.'4').AND.(J.EQ.'    ')) THEN
          WRITE (11,200) LINE
         ELSE

          IF ((I.EQ.'5').AND.(J.EQ.'    ')) THEN
           WRITE (11,200) LINE
          ELSE

           IF ((I.EQ.'6').AND.(J.EQ.'    ')) THEN
            WRITE (11,200) LINE
           ELSE

            IF ((I.EQ.'7').AND.(J.EQ.'    ')) THEN
             WRITE (11,200) LINE
            ELSE

             IF ((I.EQ.'8').AND.(J.EQ.'    ')) THEN
              WRITE (11,200) LINE
             ELSE

               IF ((I.EQ.'9').AND.(J.EQ.'    ')) THEN
                WRITE (11,200) LINE
               ELSE

                 IF ((K.EQ.'10').AND.(J.EQ.'    ')) THEN
                  WRITE (11,200) LINE
                 ELSE
```

```
                    IF ((K.EQ.'11').AND.(J.EQ.'    ')) THEN
                     WRITE (11,200) LINE
                    ELSE


                      IF ((K.EQ.'12').AND.(J.EQ.'    ')) THEN
                       WRITE (11,200) LINE
                      ENDIF

                     ENDIF

                    ENDIF

                   ENDIF

                  ENDIF

                 ENDIF

                ENDIF

               ENDIF

              ENDIF

             ENDIF

            ENDIF

           GO TO 10

777        Continue
           IF ((I.EQ.'1').AND.(J.EQ.'    ')) THEN
             WRITE (11,200) LINE
           ELSE

            IF ((I.EQ.'2').AND.(J.EQ.'    ')) THEN
             WRITE (11,200) LINE
            ELSE

             IF ((I.EQ.'3').AND.(J.EQ.'    ')) THEN
              WRITE (11,200) LINE
             ELSE

              IF ((I.EQ.'4').AND.(J.EQ.'    ')) THEN
               WRITE (11,200) LINE
              ELSE

               IF ((I.EQ.'5').AND.(J.EQ.'    ')) THEN
                WRITE (11,200) LINE
```

```
ELSE

 IF ((I.EQ.'6').AND.(J.EQ.'    ')) THEN
  WRITE (11,200) LINE
 ELSE


  IF ((I.EQ.'7').AND.(J.EQ.'    ')) THEN
   WRITE (11,200) LINE
  ELSE

   IF ((I.EQ.'8').AND.(J.EQ.'    ')) THEN
    WRITE (11,200) LINE
   ELSE

    IF ((I.EQ.'9').AND.(J.EQ.'    ')) THEN
     WRITE (11,200) LINE
    ELSE

     IF ((K.EQ.'10').AND.(J.EQ.'    ')) THEN
      WRITE (11,200) LINE
     ELSE

      IF ((K.EQ.'11').AND.(J.EQ.'    ')) THEN
       WRITE (11,200) LINE
      ELSE

       IF ((K.EQ.'12').AND.(J.EQ.'    ')) THEN
        WRITE (11,200) LINE
       ELSE

        IF ((K.EQ.'13').AND.(J.EQ.'    ')) THEN
         WRITE (11,200) LINE
        ELSE

         IF ((K.EQ.'14').AND.(J.EQ.'    ')) THEN
          WRITE (11,200) LINE
         ELSE

          IF ((K.EQ.'15').AND.(J.EQ.'    ')) THEN
           WRITE (11,200) LINE
          ELSE

           IF ((K.EQ.'16').AND.(J.EQ.'    ')) THEN
            WRITE (11,200) LINE
           ELSE

            IF ((K.EQ.'17').AND.(J.EQ.'    ')) THEN
             WRITE (11,200) LINE
            ELSE

             IF ((K.EQ.'18').AND.(J.EQ.'    ')) THEN
```

```
                    WRITE (11,200) LINE
                  ENDIF
                ENDIF
              ENDIF
            ENDIF
          ENDIF
        ENDIF
      ENDIF
    ENDIF
  ENDIF
 ENDIF
ENDIF
ENDIF
ENDIF
ENDIF
ENDIF
ENDIF
ENDIF
ENDIF
ENDIF
ENDIF
ENDIF
ENDIF
ENDIF
GO TO 10

200   Format (A80)

666   Continue
      BatchFlag=.FALSE.

888   Continue
      IF (BatchFlag) THEN
        Close(10)
        Go to 11
      ELSE
        Close(9)
```

```
        Close(10)
        Close(11)
      ENDIF

      Print *,'Filtering complete.  Analysis of data in',
     +        ' MLR.DAT has begun.',' Analysis results will',
     +        ' be dumped to ',Newout,'.'

      IF (VarFlag) THEN
        Call Stepcount3(NewOut)
      ELSE
        Call newstepcount1(NewOut)
      ENDIF
      GO TO 5

999   Continue

      Print *,'Processing complete. Program terminated.'
      Stop

* Error trap: ********************************************
1000  Continue
      Print 1100, '+++ ERROR WHILE OPENING FILE +++',
     &            '      error code = ', IERROR
1100  FORMAT(/1X, A/ 1X, A, I8/)
      GO TO 5
*************************************************************
      END
```

```
********** GEM.FOR **********

      character*12 mod
      character*12 modmse
      character*12 modsp
      character*12 modcp
      character*80 line
      character var
      integer n,num,nummse,numsp,numcp
      real minmse,mse,spms,cpms,sp,cp,msesp,cpsp,msecp,spcp
      open (unit=1,file='temp2.dat',status='old')
      open (unit=2,file='temp.dat', status='old')
      open (unit=3,file='minmod1.dat',status='new')
      do 10 I=1,1920
           read (1,500,end=200) line
           var=line(20:20)
           IF (var.EQ.'1') then
           n=1
           else
           IF (var.EQ.'2') then
           n=3
           else
           IF (var.EQ.'3') then
           n=7
           else
           IF (var.EQ.'4') then
           n=15
           endif
           endif
           endif
           endif
           minmse=1000
           minsp=1000
           mincp=1000
            do 20 j=1,n
              read (2,501,end=200) num,cp,mse,sp,mod
              IF (mse.LE.minmse) then
              minmse=mse
              spms=sp
              cpms=cp
              modmse=mod
              nummse=num
              endif
              IF (sp.LE.minsp) then
              minsp=sp
              msesp=mse
              cpsp=cp
              modsp=mod
              numsp=num
```

```
                endif


                IF (cp.LE.mincp) then
                mincp=cp
                msecp=mse
                spcp=sp
                modcp=mod
                numcp=num
                endif
20        continue
            write (3,*)'MSE',nummse,minmse,spms,cpms,modmse
            write (3,*)'Sp ',numsp,msesp,minsp,cpsp,modsp
            write (3,*)'Cp ',numcp,msecp,spcp,mincp,modcp

10        continue
500       format (A80)
501       format (7X,I1,17X,F9.5,3X,F9.7,2X,F10.8,2X,A12)
200       stop
          end
```

```
********************  GEM3.FOR **********************

      character*12 mod
      character*12 modmse
      character*12 modsp
      character*12 modcp
      character*80 line
      character var
      integer n,num,nummse,numsp,numcp
      real minmse,mse,spms,cpms,sp,cp,msesp,cpsp,msecp,spcp
      open (unit=1,file='temp22.dat',status='old')
      open (unit=2,file='temp33.dat', status='old')
      open (unit=3,file='minmod3.dat',status='new')
      do 10 I=1,50000
           read (1,500,end=200) line
           var=line(20:20)
           IF (var.EQ.'1') then
           n=1
           else
           IF (var.EQ.'2') then
           n=3
           else
           IF (var.EQ.'3') then
           n=7
           else
           IF (var.EQ.'4') then
           n=15
           IF (var.EQ.'5') then
           n=31
           IF (var.EQ.'6') then
           n=63
           endif
           endif
           endif
           endif
           endif
           endif
           minmse=1000
           minsp=1000
           mincp=1000
            do 20 j=1,n
              read (2,501,end=200) num,cp,mse,sp,mod
              IF (mse.LE.minmse) then
              minmse=mse
              spms=sp
              cpms=cp
              modmse=mod
              nummse=num
              endif
```

```
                IF (sp.LE.minsp) then
                minsp=sp
                msesp=mse
                cpsp=cp
                modsp=mod
                numsp=num
                endif
                IF (cp.LE.mincp) then
                mincp=cp
                msecp=mse
                spcp=sp
                modcp=mod
                numcp=num
                endif
20        continue
            write (3,*)'MSE',nummse,minmse,spms,cpms,modmse
            write (3,*)'Sp ',numsp,msesp,minsp,cpsp,modsp
            write (3,*)'Cp ',numcp,msecp,spcp,mincp,modcp

10        continue
500       format (A80)
501       format (7X,I1,17X,F9.5,3X,F9.7,2X,F10.8,2X,A12)
200       stop
          end
```

```
************************ GRGR.FOR ****************************

      CHARACTER*12 GR
      OPEN(UNIT=1,FILE= 'TEMP2.dat',STATUS='old')
      OPEN(UNIT=2,FILE='SCRN1.SAS',STATUS='new')
      DO 40 K=1,63,2
      PRINT*,'K=',K
      WRITE(2,*) 'option linesize=80;'
      WRITE(2,*) 'filename new ''01.dat'';'
      WRITE(2,*) 'data new;'
      WRITE(2,*) 'infile new ;'
      WRITE(2,*) 'input z y x1 x2 x3 x4 e1;'
      DO 50 J=1,60
          READ(1,500,END=200) GR
          WRITE(2,501) J,GR
50    CONTINUE
40    CONTINUE
500   FORMAT(26X,A12)
501   FORMAT(' proc rsquare data=new mse sp cp;' /
     1        '  where z=' ,I2,';' /
     2        '  model y=',A12,';' )
200   STOP
      END
```

```
************************ GRGR3.FOR ************************

      CHARACTER*12 GR
      OPEN(UNIT=1,FILE= 'TEMP22.dat',STATUS='OLD')
      OPEN(UNIT=2,FILE='SCRN11.SAS',STATUS='NEW')
      DO 40 K=2,64,2
      WRITE(2,*) 'option linesize=80;'
      WRITE(2,*) 'filename new '' ',k,'.dat'';'
      WRITE(2,*) 'data new;'
      WRITE(2,*) 'infile new ;'
      WRITE(2,*) 'input z y x1 x2 x3 x4 e1 e2 e3;'
      DO 50 J=1,60
          READ(1,500,END=200) GR
          WRITE(2,501) J,GR
50    CONTINUE
40    CONTINUE
500   FORMAT(26X,A12)
501   FORMAT(' proc rsquare data=new mse sp cp;' /
     1        '  where z=' ,I2,';' /
     2        '  model y=',A12,';' )
200   STOP
      END
```

```
************************** HALFMLR.FOR **********************

      open (unit=2,file='hlfmlr80.sas',status='new')
      WRITE(2,*) 'option linesize=80 pagesize=57;'
      DO 40 K=18,48,2
      WRITE(2,*) 'filename new '' ',K,'.dat'';'
      WRITE(2,*) 'data dataset;'
      WRITE(2,*) 'infile new ;'
      WRITE(2,*) 'input set y x1 x2 x3 x4 e1 e2 e3;'
      WRITE(2,*) 'data randset;'
      WRITE(2,*) 'set dataset;'
      WRITE(2,*) 'r1=RANNOR(0);'
      WRITE(2,*) 'r2=RANNOR(0);'
      WRITE(2,*) 'r3=RANNOR(0);'
      WRITE(2,*) 'r4=RANNOR(0);'
      WRITE(2,*) 'r5=RANNOR(0);'
      WRITE(2,*) 'r6=RANNOR(0);'
      WRITE(2,*) 'r7=RANNOR(0);'
      WRITE(2,*) 'r8=RANNOR(0);'
      WRITE(2,*) 'r9=RANNOR(0);'
      WRITE(2,*) 'proc stepwise data=randset;'
      WRITE(2,*) 'by set;'
      WRITE(2,*) 'model y=x1 x2 x3 e1 e2 e3 r1 r2 r3
     + r4 r5 r6 r7 r8 r9 /forward slentry=1;'
40    CONTINUE
      END
```

```
********************** INVMSE103.FOR ************************

      character*2 m1,m2,m3,m4,m5,m6
      character*3 m
      character*80 line
      open (unit=1,file='error3_all.dat',status='old')
      open (unit=2,file='invmse103.sas',status='new')
      do 40 k=2,64,2
       do 50 j=1,60
70       read(1,500,end=200) line
         m= line(2:4)
         m1= line(63:64)
         m2= line(65:66)
         m3= line(67:68)
         m4= line(69:70)
         m5= line(71:72)
         m6= line(73:74)

       if ((m.EQ.'MSE').AND.(m2.EQ.'  ')) then
       write(2,*) 'option linesize=80 pagesize=57 ;'
       write(2,*) 'filename new '' ',k,'.dat'';'
       write(2,*) 'data dataset;'
       write(2,*) 'infile new;'
       write(2,*) 'input set y x1 x2 x3 x4 e1 e2 e3;'
       write(2,*) 'data randset;'
       write(2,*) 'set dataset;'
       write(2,*) 'r1=RANNOR(0);'
       write(2,*) 'proc stepwise data=randset ;'
       write(2,*) 'where set=',j,';'
       write(2,*)'model y=',m1,' r1 /forward slentry=1;'
         else

         if ((m.EQ.'MSE').AND.(m3.EQ.'  ')) then
       write(2,*) 'option linesize=80 pagesize=57 ;'
       write(2,*) 'filename new'' ',k,'.dat'';'
       write(2,*) 'data dataset;'
       write(2,*) 'infile new;'
       write(2,*) 'input set y x1 x2 x3 x4 e1 e2 e3;'
       write(2,*) 'data randset;'
       write(2,*) 'set dataset;'
       write(2,*) 'r1=RANNOR(0);'
       write(2,*) 'r2=RANNOR(0);'
       write(2,*) 'proc stepwise data=randset ;'
       write(2,*) 'where set=',j,';'
       write(2,*) 'model y=',m1,' ',m2,
     +             ' r1 r2 /forward slentry=1;'
         else

         if((m.EQ.'MSE').AND.(m4.EQ.'  ')) then
```

```
      write(2,*) 'option linesize=80 pagesize=57 ;'
      write(2,*) 'filename new'' ',k,'.dat'';'
      write(2,*) 'data dataset;'
      write(2,*) 'infile new;'
      write(2,*) 'input set y x1 x2 x3 x4 e1 e2 e3;'
      write(2,*) 'data randset;'
      write(2,*) 'set dataset;'
      write(2,*) 'r1=RANNOR(0);'
      write(2,*) 'r2=RANNOR(0);'
      write(2,*) 'r3=RANNOR(0);'
      write(2,*) 'proc stepwise data=randset ;'
      write(2,*) 'where set=',j,';'
      write(2,*) 'model y=',m1,' ',m2,' ',m3,
     +             ' r1 r2 r3/forward slentry=1;'
        else

        if ((m.EQ.'MSE').AND.(m5.EQ.'  ')) then
     write(2,*) 'option linesize=80 pagesize=57 ;'
     write(2,*) 'filename new'' ',k,'.dat'';'
     write(2,*) 'data dataset;'
     write(2,*) 'infile new;'
     write(2,*) 'input set y x1 x2 x3 x4 e1 e2 e3;'
     write(2,*) 'data randset;'
     write(2,*) 'set dataset;'
     write(2,*) 'r1=RANNOR(0);'
     write(2,*) 'r2=RANNOR(0);'
     write(2,*) 'r3=RANNOR(0);'
     write(2,*) 'r4=RANNOR(0);'
     write(2,*) 'proc stepwise data=randset ;'
     write(2,*) 'where set=',j,';'
     write(2,*) 'model y=',m1,' ',m2,' ',m3,' ',m4,
     +             ' r1 r2 r3 r4 /forward slentry=1;'

     else

        if ((m.EQ.'MSE').AND.(m6.EQ.'  ')) then
     write(2,*) 'option linesize=80 pagesize=57 ;'
     write(2,*) 'filename new'' ',k,'.dat'';'
     write(2,*) 'data dataset;'
     write(2,*) 'infile new;'
     write(2,*) 'input set y x1 x2 x3 x4 e1 e2 e3;'
     write(2,*) 'data randset;'
     write(2,*) 'set dataset;'
     write(2,*) 'r1=RANNOR(0);'
     write(2,*) 'r2=RANNOR(0);'
     write(2,*) 'r3=RANNOR(0);'
     write(2,*) 'r4=RANNOR(0);'
     write(2,*) 'r5=RANNOR(0);'
     write(2,*) 'proc stepwise data=randset ;'
```

```
      write(2,*) 'where set=',j,';'



      write(2,*) 'model y=',m1,' ',m2,' ',m3,' ',m4,' ',m5,
     +             ' r1 r2 r3 r4 r5 /forward slentry=1;'
      else

          if ((m.EQ.'MSE').AND.(m6.NE.'  ')) then
      write(2,*) 'option linesize=80 pagesize=57 ;'
      write(2,*) 'filename new'' ',k,'.dat'';'
      write(2,*) 'data dataset;'
      write(2,*) 'infile new;'
      write(2,*) 'input set y x1 x2 x3 x4 e1 e2 e3;'
      write(2,*) 'data randset;'
      write(2,*) 'set dataset;'
      write(2,*) 'r1=RANNOR(0);'
      write(2,*) 'r2=RANNOR(0);'
      write(2,*) 'r3=RANNOR(0);'
      write(2,*) 'r4=RANNOR(0);'
      write(2,*) 'r5=RANNOR(0);'
      write(2,*) 'r6=RANNOR(0);'
      write(2,*) 'proc stepwise data=randset ;'
      write(2,*) 'where set=',j,';'
      write(2,*) 'model y=',m1,' ',m2,' ',m3,' ',m4,' ',m5,'
     + ',m6,' r1 r2 r3 r4 r5 r6 /forward slentry=1;'

        else
         goto 70
         endif
         endif
         endif
         endif
         endif
         endif
50      continue
40     continue
500    format(A80)
200    stop
       end
```

```
********************************* INVSP101.FOR ***********************

      character*2 m1,m2,m3,m4
      character*2 m
      character*80 line
      open (unit=1,file='error1_all.dat',status='old')
      open (unit=2,file='invsp101.sas',status='new')
      do 40 k=1,63,2
        do 50 j=1,60
70        read(1,500,end=200) line
          m= line(2:8)
          m1= line(63:64)
          m2= line(65:66)
          m3= line(67:68)
          m4= line(69:70)

        if ((m.EQ.'Sp     ').AND.(m2.EQ.'  ')) then
        write(2,*) 'option linesize=80 pagesize=57 ;'
        write(2,*) 'filename new '' ',k,'.dat'';'
        write(2,*) 'data dataset;'
        write(2,*) 'infile new;'
        write(2,*) 'input set y x1 x2 x3 x4 e1;'
        write(2,*) 'data randset;'
        write(2,*) 'set dataset;'
        write(2,*) 'r1=RANNOR(0);'
        write(2,*) 'proc stepwise data=randset ;'
        write(2,*) 'where set=',j,';'
        write(2,*)'model y=',m1,' r1 /forward slentry=1;'
          else

          if ((m.EQ.'Sp     ').AND.(m3.EQ.'  ')) then
        write(2,*) 'option linesize=80 pagesize=57 ;'
        write(2,*) 'filename new'' ',k,'.dat'';'
        write(2,*) 'data dataset;'
        write(2,*) 'infile new;'
        write(2,*) 'input set y x1 x2 x3 x4 e1;'
        write(2,*) 'data randset;'
        write(2,*) 'set dataset;'
        write(2,*) 'r1=RANNOR(0);'
        write(2,*) 'r2=RANNOR(0);'
        write(2,*) 'proc stepwise data=randset ;'
        write(2,*) 'where set=',j,';'
        write(2,*) 'model y=',m1,' ',m2,
     +             ' r1 r2 /forward slentry=1;'
          else

          if((m.EQ.'Sp     ').AND.(m4.EQ.'  ')) then
       write(2,*) 'option linesize=80 pagesize=57 ;'
       write(2,*) 'filename new'' ',k,'.dat'';'
```

```
          write(2,*) 'data dataset;'
          write(2,*) 'infile new;'
          write(2,*) 'input set y x1 x2 x3 x4 e1;'
          write(2,*) 'data randset;'
          write(2,*) 'set dataset;'
          write(2,*) 'r1=RANNOR(0);'
          write(2,*) 'r2=RANNOR(0);'
          write(2,*) 'r3=RANNOR(0);'
          write(2,*) 'proc stepwise data=randset ;'
          write(2,*) 'where set=',j,';'
          write(2,*) 'model y=',m1,' ',m2,' ',m3,
     +               ' r1 r2 r3 /forward slentry=1;'
            else

            if ((m.EQ.'Sp     ').AND.(m4.NE.'   ')) then
          write(2,*) 'option linesize=80 pagesize=57 ;'
          write(2,*) 'filename new'' ',k,'.dat'';'
          write(2,*) 'data dataset;'
          write(2,*) 'infile new;'
          write(2,*) 'input set y x1 x2 x3 x4 e1;'
          write(2,*) 'data randset;'
          write(2,*) 'set dataset;'
          write(2,*) 'r1=RANNOR(0);'
          write(2,*) 'r2=RANNOR(0);'
          write(2,*) 'r3=RANNOR(0);'
          write(2,*) 'r4=RANNOR(0);'
          write(2,*) 'proc stepwise data=randset ;'
          write(2,*) 'where set=',j,';'
          write(2,*) 'model y=',m1,' ',m2,' ',m3,' ',m4,
     +               ' r1 r2 r3 r4 /forward slentry=1;'
           else
            goto 70
            endif
            endif
            endif
            endif
50         continue
40        continue
500       format(A80)
200       stop
          end
```

```
************************** INVSP103.FOR **********************

      character*2 m1,m2,m3,m4,m5,m6
      character*3 m
      character*80 line
      open (unit=1,file='error3_all.dat',status='old')
      open (unit=2,file='invsp103.sas',status='new')
      do 40 k=2,64,2
        do 50 j=1,60
70        read(1,500,end=200) line
          m= line(2:8)
          m1= line(63:64)
          m2= line(65:66)
          m3= line(67:68)
          m4= line(69:70)
          m5= line(71:72)
          m6= line(73:74)

       if ((m.EQ.'Sp     ').AND.(m2.EQ.'  ')) then
       write(2,*) 'option linesize=80 pagesize=57 ;'
       write(2,*) 'filename new '' ',k,'.dat'';'
       write(2,*) 'data dataset;'
       write(2,*) 'infile new;'
       write(2,*) 'input set y x1 x2 x3 x4 e1 e2 e3;'
       write(2,*) 'data randset;'
       write(2,*) 'set dataset;'
       write(2,*) 'r1=RANNOR(0);'
       write(2,*) 'proc stepwise data=randset ;'
       write(2,*) 'where set=',j,';'
       write(2,*)'model y=',m1,' r1 /forward slentry=1;'
          else

          if ((m.EQ.'Sp     ').AND.(m3.EQ.'  ')) then
       write(2,*) 'option linesize=80 pagesize=57 ;'
       write(2,*) 'filename new'' ',k,'.dat'';'
       write(2,*) 'data dataset;'
       write(2,*) 'infile new;'
       write(2,*) 'input set y x1 x2 x3 x4 e1 e2 e3;'
       write(2,*) 'data randset;'
       write(2,*) 'set dataset;'
       write(2,*) 'r1=RANNOR(0);'
       write(2,*) 'r2=RANNOR(0);'
       write(2,*) 'proc stepwise data=randset ;'
       write(2,*) 'where set=',j,';'
       write(2,*) 'model y=',m1,' ',m2,
     +    ' r1 r2 /forward slentry=1;'
          else
          if((m.EQ.'Sp     ').AND.(m4.EQ.'  ')) then
```

```
      write(2,*) 'option linesize=80 pagesize=57 ;'
      write(2,*) 'filename new'' ',k,'.dat'';'
      write(2,*) 'data dataset;'
      write(2,*) 'infile new;'
      write(2,*) 'input set y x1 x2 x3 x4 e1 e2 e3;'
      write(2,*) 'data randset;'
      write(2,*) 'set dataset;'
      write(2,*) 'r1=RANNOR(0);'
      write(2,*) 'r2=RANNOR(0);'
      write(2,*) 'r3=RANNOR(0);'
      write(2,*) 'proc stepwise data=randset ;'
      write(2,*) 'where set=',j,';'
      write(2,*) 'model y=',m1,' ',m2,' ',m3,
     +    ' r1 r2 r3/forward slentry=1;'
         else

         if ((m.EQ.'Sp     ').AND.(m5.EQ.'  ')) then
      write(2,*) 'option linesize=80 pagesize=57 ;'
      write(2,*) 'filename new'' ',k,'.dat'';'
      write(2,*) 'data dataset;'
      write(2,*) 'infile new;'
      write(2,*) 'input set y x1 x2 x3 x4 e1 e2 e3;'
      write(2,*) 'data randset;'
      write(2,*) 'set dataset;'
      write(2,*) 'r1=RANNOR(0);'
      write(2,*) 'r2=RANNOR(0);'
      write(2,*) 'r3=RANNOR(0);'
      write(2,*) 'r4=RANNOR(0);'
      write(2,*) 'proc stepwise data=randset ;'
      write(2,*) 'where set=',j,';'
      write(2,*) 'model y=',m1,' ',m2,' ',m3,' ',m4,
     +   ' r1 r2 r3 r4 /forward slentry=1;'

      else

         if ((m.EQ.'Sp     ').AND.(m6.EQ.'  ')) then
      write(2,*) 'option linesize=80 pagesize=57 ;'
      write(2,*) 'filename new'' ',k,'.dat'';'
      write(2,*) 'data dataset;'
      write(2,*) 'infile new;'
      write(2,*) 'input set y x1 x2 x3 x4 e1 e2 e3;'
      write(2,*) 'data randset;'
      write(2,*) 'set dataset;'
      write(2,*) 'r1=RANNOR(0);'
      write(2,*) 'r2=RANNOR(0);'
      write(2,*) 'r3=RANNOR(0);'
      write(2,*) 'r4=RANNOR(0);'
      write(2,*) 'r5=RANNOR(0);'
      write(2,*) 'proc stepwise data=randset ;'
      write(2,*) 'where set=',j,';'
```

```
      write(2,*) 'model y=',m1,' ',m2,' ',m3,' ',m4,' ',m5,
     +   ' r1 r2 r3 r4 r5 /forward slentry=1;'
      else

          if ((m.EQ.'Sp     ').AND.(m6.NE.'   ')) then
      write(2,*) 'option linesize=80 pagesize=57 ;'
      write(2,*) 'filename new'' ',k,'.dat'';'
      write(2,*) 'data dataset;'
      write(2,*) 'infile new;'
      write(2,*) 'input set y x1 x2 x3 x4 e1 e2 e3;'
      write(2,*) 'data randset;'
      write(2,*) 'set dataset;'
      write(2,*) 'r1=RANNOR(0);'
      write(2,*) 'r2=RANNOR(0);'
      write(2,*) 'r3=RANNOR(0);'
      write(2,*) 'r4=RANNOR(0);'
      write(2,*) 'r5=RANNOR(0);'
      write(2,*) 'r6=RANNOR(0);'
      write(2,*) 'proc stepwise data=randset ;'
      write(2,*) 'where set=',j,';'
      write(2,*) 'model y=',m1,' ',m2,' ',m3,' ',m4,' ',m5,'
',m6,
     +   ' r1 r2 r3 r4 r5 r6 /forward slentry=1;'

        else
         goto 70
         endif
         endif
         endif
         endif
         endif
         endif
50      continue
40     continue
500    format(A80)
200    stop
       end
```

```
************************** LESSMLR.FOR ************************

      open (unit=2,file='less30.sas',status='new')
      WRITE(2,*) 'option linesize=80 pagesize=57 ;'
      DO 40 K=1,63,2
      WRITE(2,*) 'filename new ''01.dat'';'
      WRITE(2,*) 'data dataset;'
      WRITE(2,*) 'infile new ;'
      WRITE(2,*) 'input set y x1 x2 x3 x4 e1 ;'
      WRITE(2,*) 'data randset;'
      WRITE(2,*) 'set dataset;'
      WRITE(2,*) 'r1=RANNOR(0);'
      WRITE(2,*) 'r2=RANNOR(0);'
      WRITE(2,*) 'proc stepwise data=randset;'
      WRITE(2,*) 'by set;'
      WRITE(2,*) 'model y=x1 x2 x3 e1 r1 r2
     +  /forward  slentry=1;'
40    CONTINUE
      END
```

```
********************** MM1_47.FOR ********************

      character*80 LINE(6)
      character*1 NUM(6)
      integer z(6)
      open(unit=1, file='onemlr10.dat',status='old')
      open(unit=2, file='onemlr11.dat',status='old')
      open(unit=3, file='onemlr12.dat',status='old')
      open(unit=4, file='onemlr13.dat',status='old')
      open(unit=5, file='onemlr14.dat',status='old')
      open(unit=6, file='onemlr15.dat',status='old')
      open(unit=7, file='mm1_47.dat',status='new')
      DO 1 v=1,1500
      DO 2 s=1,6
      READ(s,500,end=200) LINE(s)
      NUM(s)=LINE(s) (20:20)
2     CONTINUE
      DO 5 j=1,6
      z(j)=0
5     CONTINUE

       DO 10 k=1,6
       IF((NUM(1).EQ.NUM(k)).AND.(LINE(1)(21:23).EQ.'   '))
      +z(1)=z(1)+1
10     CONTINUE

       DO 20 a=1,6
       IF((NUM(2).EQ.NUM(a)).AND.(LINE(1)(21:23).EQ.'   '))
      +z(2)=z(2)+1
20     CONTINUE

       DO 30 b=1,6
       IF((NUM(3).EQ.NUM(b)).AND.(LINE(1)(21:23).EQ.'   '))
      +z(3)=z(3)+1
30     CONTINUE

       DO 40 c=1,6
       IF((NUM(4).EQ.NUM(c)).AND.(LINE(1)(21:23).EQ.'   '))
      +z(4)=z(4)+1
40     CONTINUE

       DO 50 d=1,6
       IF((NUM(5).EQ.NUM(d)).AND.(LINE(1)(21:23).EQ.'   '))
      +z(5)=z(5)+1
50     CONTINUE

       DO 60 e=1,6
       IF((NUM(6).EQ.NUM(e)).AND.(LINE(1)(21:23).EQ.'   '))
      +z(6)=z(6)+1
60     CONTINUE
```

```
********** MM17_63.FOR **********

      character*80 LINE(6)
      character*1 NUM(6)
      integer z(6)
      open(unit=1, file='hlfmlr10.dat',status='old')
      open(unit=2, file='hlfmlr11.dat',status='old')
      open(unit=3, file='hlfmlr12.dat',status='old')
      open(unit=4, file='hlfmlr13.dat',status='old')
      open(unit=5, file='hlfmlr14.dat',status='old')
      open(unit=6, file='hlfmlr15.dat',status='old')
      open(unit=7, file='mm17_63.dat',status='new')
      DO 1 v=1,1500
      DO 2 s=1,6
      READ(s,500,end=200) LINE(s)
      NUM(s)=LINE(s) (20:20)
2     CONTINUE
      DO 5 j=1,6
      z(j)=0
5     CONTINUE

       DO 10 k=1,6
       IF((NUM(1).EQ.NUM(k)).AND.(LINE(1)(21:23).EQ.'    '))
      + z(1)=z(1)+1
10     CONTINUE

       DO 20 a=1,6
       IF((NUM(2).EQ.NUM(a)).AND.(LINE(1)(21:23).EQ.'    '))
      + z(2)=z(2)+1
20     CONTINUE

       DO 30 b=1,6
       IF((NUM(3).EQ.NUM(b)).AND.(LINE(1)(21:23).EQ.'    '))
       +z(3)=z(3)+1
30     CONTINUE

      DO 40 c=1,6
       IF((NUM(4).EQ.NUM(c)).AND.(LINE(1)(21:23).EQ.'    '))
      + z(4)=z(4)+1
40     CONTINUE

      DO 50 d=1,6
       IF((NUM(5).EQ.NUM(d)).AND.(LINE(1)(21:23).EQ.'    '))
     + z(5)=z(5)+1
50     CONTINUE

      DO 60 e=1,6
       IF((NUM(6).EQ.NUM(e)).AND.(LINE(1)(21:23).EQ.'    '))
     + z(6)=z(6)+1
```

```
60      CONTINUE

        BIG=0
        DO 100 f=1,6
        IF (z(f).GT.BIG)  BIG=z(f)
100     CONTINUE

        IF (z(1).EQ.BIG) THEN
        WRITE(7,*) LINE(1)
        ELSE
        IF (z(2).EQ.BIG) THEN
        WRITE(7,*) LINE(2)
        ELSE
        IF (z(3).EQ.BIG) THEN
        WRITE(7,*) LINE(3)
        ELSE
        IF (z(4).EQ.BIG) THEN
        ELSE
        IF (z(5).EQ.BIG) THEN
        WRITE(7,*) LINE(5)
        ELSE
        IF (z(6).EQ.BIG) THEN
        WRITE(7,*) LINE(6)
        ELSE
        WRITE(7,*) 'IT IS TIE.'
             ENDIF
            ENDIF
           ENDIF
          ENDIF
         ENDIF
        ENDIF

1       CONTINUE

500     format(A80)
200     stop
        end
```

```
********************************* MM18_64.FOR **********************

      character*80 LINE(6)
      character*1 NUM(6)
      integer z(6)
      open(unit=1, file='hlfmlr80.dat',status='old')
      open(unit=2, file='hlfmlr81.dat',status='old')
      open(unit=3, file='hlfmlr82.dat',status='old')
      open(unit=4, file='hlfmlr83.dat',status='old')
      open(unit=5, file='hlfmlr84.dat',status='old')
      open(unit=6, file='hlfmlr85.dat',status='old')
      open(unit=7, file='mm18_64.dat',status='new')
      DO 1 v=1,1500
      DO 2 s=1,6
      READ(s,500,end=200) LINE(s)
      NUM(s)=LINE(s) (20:20)
2     CONTINUE
      DO 5 j=1,6
      z(j)=0
5     CONTINUE

       DO 10 k=1,6
       IF((NUM(1).EQ.NUM(k)).AND.(LINE(1)(21:23).EQ.'   '))
      + z(1)=z(1)+1
10     CONTINUE

       DO 20 a=1,6
       IF((NUM(2).EQ.NUM(a)).AND.(LINE(1)(21:23).EQ.'   '))
      + z(2)=z(2)+1
20     CONTINUE

       DO 30 b=1,6
       IF((NUM(3).EQ.NUM(b)).AND.(LINE(1)(21:23).EQ.'   '))
      + z(3)=z(3)+1
30     CONTINUE

      DO 40 c=1,6
       IF((NUM(4).EQ.NUM(c)).AND.(LINE(1)(21:23).EQ.'   '))
     + z(4)=z(4)+1
40     CONTINUE

      DO 50 d=1,6
       IF((NUM(5).EQ.NUM(d)).AND.(LINE(1)(21:23).EQ.'   '))
     + z(5)=z(5)+1
50     CONTINUE

      DO 60 e=1,6
       IF((NUM(6).EQ.NUM(e)).AND.(LINE(1)(21:23).EQ.'   '))
     + z(6)=z(6)+1
```

```
60      CONTINUE

        BIG=0
        DO 100 f=1,6
        IF (z(f).GT.BIG)  BIG=z(f)
100     CONTINUE

        IF (z(1).EQ.BIG) THEN
        WRITE(7,*) LINE(1)
        ELSE
        IF (z(2).EQ.BIG) THEN
        WRITE(7,*) LINE(2)
        ELSE
        IF (z(3).EQ.BIG) THEN
        WRITE(7,*) LINE(3)
        ELSE
        IF (z(4).EQ.BIG) THEN
        ELSE
        IF (z(5).EQ.BIG) THEN
        WRITE(7,*) LINE(5)
        ELSE
        IF (z(6).EQ.BIG) THEN
        WRITE(7,*) LINE(6)
        ELSE
        WRITE(7,*) 'IT IS TIE.'
             ENDIF
            ENDIF
           ENDIF
          ENDIF
         ENDIF
        ENDIF

1       CONTINUE

500     format(A80)
200     stop
        end
```

```
****************************** MM2_48.FOR **********************

      character*80 LINE(6)
      character*1 NUM(6)
      integer z(6)
      open(unit=1, file='onemlr80.dat',status='old')
      open(unit=2, file='onemlr81.dat',status='old')
      open(unit=3, file='onemlr82.dat',status='old')
      open(unit=4, file='onemlr83.dat',status='old')
      open(unit=5, file='onemlr84.dat',status='old')
      open(unit=6, file='onemlr85.dat',status='old')
      open(unit=7, file='mm2_48.dat',status='new')
      DO 1 v=1,1500
      DO 2 s=1,6
      READ(s,500,end=200) LINE(s)
      NUM(s)=LINE(s) (20:20)
2     CONTINUE
      DO 5 j=1,6
      z(j)=0
5     CONTINUE

       DO 10 k=1,6
       IF((NUM(1).EQ.NUM(k)).AND.(LINE(1)(21:23).EQ.'    '))
      + z(1)=z(1)+1
10     CONTINUE

       DO 20 a=1,6
       IF((NUM(2).EQ.NUM(a)).AND.(LINE(1)(21:23).EQ.'    '))
      + z(2)=z(2)+1
20     CONTINUE

       DO 30 b=1,6
       IF((NUM(3).EQ.NUM(b)).AND.(LINE(1)(21:23).EQ.'    '))
      + z(3)=z(3)+1
30     CONTINUE

      DO 40 c=1,6
       IF((NUM(4).EQ.NUM(c)).AND.(LINE(1)(21:23).EQ.'    '))
      + z(4)=z(4)+1
40     CONTINUE

      DO 50 d=1,6
       IF((NUM(5).EQ.NUM(d)).AND.(LINE(1)(21:23).EQ.'    '))
     + z(5)=z(5)+1
50     CONTINUE

      DO 60 e=1,6
       IF((NUM(6).EQ.NUM(e)).AND.(LINE(1)(21:23).EQ.'    '))
     + z(6)=z(6)+1
```

```
60      CONTINUE

        BIG=0
        DO 100 f=1,6
        IF (z(f).GT.BIG)  BIG=z(f)
100     CONTINUE

        IF (z(1).EQ.BIG) THEN
        WRITE(7,*) LINE(1)
        ELSE
        IF (z(2).EQ.BIG) THEN
        WRITE(7,*) LINE(2)
        ELSE
        IF (z(3).EQ.BIG) THEN
        WRITE(7,*) LINE(3)
        ELSE
        IF (z(4).EQ.BIG) THEN
        ELSE
        IF (z(5).EQ.BIG) THEN
        WRITE(7,*) LINE(5)
        ELSE
        IF (z(6).EQ.BIG) THEN
        WRITE(7,*) LINE(6)
        ELSE
        WRITE(7,*) 'IT IS TIE.'
             ENDIF
            ENDIF
           ENDIF
          ENDIF
         ENDIF
        ENDIF

1       CONTINUE

500     format(A80)
200     stop
        end
```

```
************************** NEWSTEPCOUNT1.FOR ********************

      SUBROUTINE newstepcount1 (NewOut)

      integer num, numvar,h,i,j,k,n,p,q,r,s,t,v,w,x,y,z
      integer emiller, varsmiller, cumemiller, cmiller
      integer chartmiller(0:3,0:3), ReadCount
      real avgvars, avgevars, millerpm
      character*2 numchar
      character*2 m(12), Model_var, Good_model(5)
      character*20 NewOut
      character*80 line
      logical ModelNotFound, EndofFile

      num=0
      emiller=0
      varsmiller=0
      cumemiller=0
      cmiller=0
      ReadCount=0
      ModelNotFound=.TRUE.
      EndofFile=.FALSE.


      do 10 i=1,12
         m(i)='  '
10    continue

      do 20 j=1,4
         Good_model(j)='  '
20    continue

      do 30 k=0,3
        do 40 h=0,3
          chartmiller(k,h)=0
40      continue
30    continue

      open (unit=11, file='mlr.dat', status='old',
     +      iostat=IERROR, err=1000)
      open (unit=12, file=NewOut, status='new',
     +       iostat=IERROR, err=1000)
      open (unit=13, file='newPMstep1.dat', status='new',
     +       iostat=IERROR, err=1000)
      write(13,*)'     DESIGNPOINT  MILLER''S PM'

      ReadCount=ReadCount+1
         Read(11,900,end=90) line
      numchar=line (4:5)
      Model_var=line (10:11)
```

```
900         Format(A80)
          PRINT*,numchar
            IF (numchar.EQ.' 1') THEN
              num=1
            ELSE
             IF (numchar.EQ.' 2') THEN
               num=2
             ELSE
              IF (numchar.EQ.' 3') THEN
                num=3
              ELSE
               IF (numchar.EQ.' 4') THEN
                 num=4
               ELSE
                IF (numchar.EQ.' 5') THEN
                  num=5
                ELSE
                 IF (numchar.EQ.' 6') THEN
                   num=6
                 ELSE
                  IF (numchar.EQ.' 7') THEN
                    num=7
                  ELSE
                   IF (numchar.EQ.' 8') THEN
                     num=8
                   ELSE
                    IF (numchar.EQ.' 9') then
                      num=9
                    else
                     IF (numchar.EQ.'10') then
                       num=10
                     else
                      IF (numchar.EQ.'11') then
                        num=11
                      else
                       IF (numchar.EQ.'12') then
                         num=12
                       else
                    Print *, 'Unexpected format in TEMP.DAT: ',
     +                       'Numbers 1,2,3, etc., not found!(1)'
                    Go to 1300
                       ENDIF
                      ENDIF
                     ENDIF
                    ENDIF
                   ENDIF
                  ENDIF
                 ENDIF
                ENDIF
               ENDIF
              ENDIF
             ENDIF
            ENDIF
```

```
            ENDIF
           ENDIF
          ENDIF

       IF (num.NE.1) THEN
            Print *,'Processing terminated.  Input file ',
     +              'in unexpected format: 1st number must be 1.'
            Go to 1300
          ELSE
            m(num)=Model_var
          ENDIF

         Do 60 n=1,63,2
          Write(12,*)' '
          Write(12,*)' '
          Write(12,*)' '
          Write(12,*) '********************* DESIGN POINT ',
     +                n,' *********************'
          Write (12,*)' '
          Write(12,*)'Replication    #Vars    Model'

          do 70 p=1,60

80          Continue
            IF (EndofFile) THEN
              Print *,'Unexpected file format!  File does not ',
     +                'have correct # of design points and reps.'
              Go to 1300
            ENDIF
            ReadCount=ReadCount+1
            Read(11,900,end=90) line
            numchar= line (4:5)
            Model_var= line (10:11)
             IF (numchar.EQ.' 1') THEN
               num=1
             ELSE
              IF(numchar.EQ.' 2') THEN
                num=2
              ELSE
               IF (numchar.EQ.' 3') THEN
                 num=3
               ELSE
                IF (numchar.EQ.' 4') THEN
                  num=4
                ELSE
                 IF (numchar.EQ.' 5') THEN
                   num=5
                 ELSE
                  IF (numchar.EQ.' 6') THEN
                    num=6
                  ELSE
                   IF (numchar.EQ.' 7') THEN
```

```
                    num=7
                   ELSE
                    IF (numchar.EQ.' 8') THEN
                      num=8
                    ELSE

                     IF (numchar.EQ.' 9') then
                       num=9
                     else
                      IF (numchar.EQ.'10') then
                        num=10
                      else
                        IF (numchar.EQ.'11') then
                          num=11
                        else
                         IF (numchar.EQ.'12') then
                           num=12
                         else
                     Print *, 'Unexpected format in TEMP.DAT: ',
     +                          'Numbers 1,2,3, etc., not found!'
                     Go to 1300
                        ENDIF
                       ENDIF
                      ENDIF
                     ENDIF
                    ENDIF
                   ENDIF
                  ENDIF
                 ENDIF
                ENDIF

110             Continue
                IF (num.NE.1) THEN
                     m(num)=Model_var
                ELSE
                     continue
                     do 100 q=1,4
                      IF ((m(q)(1:1).NE.'R').AND.ModelNotFound) THEN
                         Good_model(q)=m(q)
                         numvar=numvar+1
                       ELSE
                         ModelNotFound=.FALSE.
                       ENDIF
100                  continue
                     Write(12,90 1)p, numvar, (Good_model(r),r=1,4)
901                  FORMAT (' ',4X,I2,11X,I2,6X,A2,1X,A2,1X,
     +                         A2,1X,A2)
                     Go to 120
                ENDIF
```

```
              GO TO 80

120       continue
          IF (numvar.LE.0) Go to 140
          do 130 s=1,numvar
              if(m(s).EQ.'E1') then


               emiller=emiller+1
              endif
130       continue

140          varsmiller=varsmiller+numvar
             cumemiller=cumemiller+emiller
             cmiller=numvar-emiller
             chartmiller(cmiller,emiller)=chartmiller(cmiller,
     +                    emiller)+1


         do 150 t=1,12
            m(t)='  '
150      Continue

         m(num)=Model_var

         do 160 v=1,4
            Good_model(v)='  '
160      continue

         emiller=0
         numvar=0
         ModelNotFound=.TRUE.

70         continue

           write(12,*) ' '
           write(12,*) '*****************************************',
     +                 '*****************************************'
           write(12,*) ' '

           IF (varsmiller.GT.0) THEN
             avgvars = real(varsmiller)/60.0
             avgevars = real(cumemiller)/60.0
             millerpm = 1-(avgevars/avgvars)
           ELSE
             avgvars=0
             avgevars=0
             millerpm=0
           ENDIF

           write(12,*) 'The avg number of vars using Miller''s',
     +                 ' method was ', avgvars
```

```
         write(12,*) 'The avg number of extraneous vars from',
     +               ' Miller''s method was', avgevars
         write(12,*) '****** The PM for Miller''s was ',
     +                millerpm,' ******'
         write(12,*) ' '
         write(12,*) '  '
         write(12,*) 'Correct Vars (0-3, down) -VS- ',
     +                'Extraneous Vars (0-3,across)'


         write(12,*) '  '
         write(12,*) ' Table for Miller''s Method'
         write(12,*) '  '
               do 170 w=0,3
                   write(12,*) (chartmiller(w,x),x=0,3)

170              continue
         Write(13,*) n,'     ',millerpm

         do 180 y = 0,3
           do 190 z = 0,3
             chartmiller(y,z)=0
190        continue
180      continue

         varsmiller=0
         cumemiller=0

60     Continue
       Close(11)
       Close(12)
       Close(13)
       GO TO 1200

* Error trap: ******************************************

1000   Continue
       Print 1100, '+++ ERROR WHILE OPENING FILE +++',
      +            '      error code = ', IERROR
1100   FORMAT(/1X, A/ 1X, A, I8/)

*********************************************************

1200   CONTINUE
       Print *,'Counting complete.  ', NewOut,' written.'
       Go to 1300

90     Print*,'End of File encountered at line ',ReadCount
       Print*,'Design Point:',n,'  Replication:',p
       num=1
       Model_var='**'
       EndofFile=.TRUE.
```

```
      Go to 110

1300  CONTINUE
      END
```

```
****************************** ONEMLR.FOR ************************

      open (unit=2,file='onemlr10.sas',status='new')
      WRITE(2,*) 'option linesize=80 pagesize=57;'
      DO 40 K=1,31,2
      WRITE(2,*) 'filename new '' ',K,'.dat'';'
      WRITE(2,*) 'data dataset;'
      WRITE(2,*) 'infile new ;'
      WRITE(2,*) 'input set y x1 x2 x3 x4 e1;'
      WRITE(2,*) 'data randset;'
      WRITE(2,*) 'set dataset;'
      WRITE(2,*) 'r1=RANNOR(0);'
      WRITE(2,*) 'r2=RANNOR(0);'
      WRITE(2,*) 'r3=RANNOR(0);'
      WRITE(2,*) 'r4=RANNOR(0);'
      WRITE(2,*) 'proc stepwise data=randset;'
      WRITE(2,*) 'by set;'
      WRITE(2,*) 'model y=x1 x2 x3 e1 r1 r2 r3 r4
     + /forward slentry=1;'
40    CONTINUE
      END
```

```
************************** STEPCOUNT3.FOR ************************

      SUBROUTINE Stepcount3 (NewOut)

      integer num, numvar,h,i,j,k,n,p,q,r,s,t,v,w,x,y,z
      integer emiller, varsmiller, cumemiller, cmiller
      integer chartmiller(0:3,0:3), ReadCount
      real avgvars, avgevars, millerpm
      character*2 m(19), Model_var, Good_model(7), numchar
      character*20 NewOut
      character*80 line
      logical ModelNotFound, EndofFile

      num=0
      emiller=0
      varsmiller=0
      cumemiller=0
      cmiller=0
      ReadCount=0
      ModelNotFound=.TRUE.
      EndofFile=.FALSE.


      do 10 i=1,18
         m(i)='  '
10    continue

      do 20 j=1,6
         Good_model(j)='  '
20    continue

      do 30 k=0,3
        do 40 h=0,3
          chartmiller(k,h)=0
40      continue
30    continue

      open (unit=11, file='mlr.dat', status='old',
     +      iostat=IERROR, err=1000)
      open (unit=12, file=NewOut, status='new',
     +       iostat=IERROR, err=1000)
      open (unit=13, file='PMstep3.dat', status='new',
     +       iostat=IERROR, err=1000)
      write(13,*)'     DESIGNPOINT  MILLER''S PM'

      ReadCount=ReadCount+1
         Read(11,900,end=90) line
         numchar=line (4:5)
         Model_var= line (10:11)
900      Format(A80)
```

```
IF (numchar.EQ.' 1') THEN


  num=1
ELSE
 IF (numchar.EQ.' 2') THEN
   num=2
 ELSE
  IF (numchar.EQ.' 3') THEN
    num=3
  ELSE
   IF (numchar.EQ.' 4') THEN
     num=4
   ELSE
    IF (numchar.EQ.' 5') THEN
      num=5
    ELSE
     IF (numchar.EQ.' 6') THEN
       num=6
     ELSE
      IF (numchar.EQ.' 7') THEN
        num=7
      ELSE
       IF (numchar.EQ.' 8') THEN
         num=8
       ELSE
        IF (numchar.EQ.' 9') THEN
          num=9
        ELSE
         IF (numchar.EQ.'10') THEN
           num=10
         ELSE
          IF (numchar.EQ.'11') THEN
            num=11
          ELSE
           IF (numchar.EQ.'12') THEN
             num=12
           ELSE
            IF (numchar.EQ.'13') THEN
              num=13
            ELSE
              IF (numchar.EQ.'14') THEN
                num=14
              ELSE
               IF (numchar.EQ.'15') THEN
                 num=15
               ELSE
                IF (numchar.EQ.'16') THEN
                  num=16
                ELSE
                 IF (numchar.EQ.'17') THEN
                   num=17
```

```
                              ELSE
                               IF (numchar.EQ.'18') THEN
                                 num=18
                               ELSE

                            Print *, 'Unexpected format in TEMP.DAT: ',
     +                             'Numbers 1,2,3, etc., not found!'
                            Go to 1300
                                 ENDIF
                                ENDIF
                               ENDIF
                              ENDIF
                             ENDIF
                            ENDIF
                           ENDIF
                          ENDIF
                         ENDIF
                        ENDIF
                       ENDIF
                      ENDIF
                     ENDIF
                    ENDIF
                   ENDIF
                  ENDIF
                 ENDIF
                ENDIF

                IF (num.NE.1) THEN
                  Print *,'Processing terminated.  Input file ',
     +                    'in unexpected format: 1st number must be 1.'
                  Go to 1300
                ELSE
                  m(num)=Model_var
                ENDIF

             Do 60 n=2,64,2
                Write(12,*)' '
                Write(12,*)' '
                Write(12,*)' '
                Write(12,*) '******************** DESIGN POINT ',
     +                       n,' **********************'
                Write (12,*)' '
                Write(12,*)'Replication    #Vars    Model'

                do 70 p=1,60

80                Continue
                  IF (EndofFile) THEN
                    Print *,'Unexpected file format!  File does not ',
     +                      'have the correct # of design points and
reps.'
                    Go to 1300
```

```
ENDIF
ReadCount=ReadCount+1
Read(11,900,end=90) line
 numchar= line (4:5)
 Model_var= line (10:11)


 IF (numchar.EQ.' 1') THEN
   num=1
 ELSE
  IF(numchar.EQ.' 2') THEN
    num=2
  ELSE
   IF (numchar.EQ.' 3') THEN
     num=3
   ELSE
    IF (numchar.EQ.' 4') THEN
      num=4
    ELSE
     IF (numchar.EQ.' 5') THEN
       num=5
     ELSE
      IF (numchar.EQ.' 6') THEN
        num=6
      ELSE
       IF (numchar.EQ.' 7') THEN
         num=7
       ELSE
        IF (numchar.EQ.' 8') THEN
          num=8
        ELSE
         IF (numchar.EQ.' 9') THEN
           num=9
         ELSE
          IF (numchar.EQ.'10') THEN
            num=10
          ELSE
           IF (numchar.EQ.'11') THEN
             num=11
           ELSE
            IF (numchar.EQ.'12') THEN
              num=12
            ELSE
             IF (numchar.EQ.'13') THEN
               num=13
             ELSE
              IF (numchar.EQ.'14') THEN
                num=14
              ELSE
               IF (numchar.EQ.'15') THEN
                 num=15
               ELSE
```

```
                                IF (numchar.EQ.'16') THEN
                                  num=16
                                ELSE
                                 IF (numchar.EQ.'17') THEN
                                   num=17
                                 ELSE
                                  IF (numchar.EQ.'18') THEN


                                     num=18

                                  ELSE

                                Print *, 'Unexpected format in MLR.DAT:
',
     +                                        'Numbers 1,2,3, etc., not
found!'
                                Go to 1300
                                     ENDIF
                                    ENDIF
                                   ENDIF
                                  ENDIF
                                 ENDIF
                                ENDIF
                               ENDIF
                              ENDIF
                             ENDIF
                            ENDIF
                           ENDIF
                          ENDIF
                         ENDIF
                        ENDIF
                       ENDIF
                      ENDIF
                     ENDIF
                    ENDIF
                   ENDIF
                  ENDIF
                 ENDIF
                ENDIF

110             Continue
                IF (num.NE.1) THEN
                     m(num)=Model_var
                ELSE
                     continue
                     do 100 q=1,6
                      IF ((m(q)(1:1).NE.'R').AND.ModelNotFound) THEN
                        Good_model(q)=m(q)
                        numvar=numvar+1
                       ELSE
                        ModelNotFound=.FALSE.
                       ENDIF
100                  continue
                     Write(12,901)p, numvar, (Good_model(r),r=1,6)
901                  FORMAT (' ',4X,I2,11X,I2,6X,A2,1X,A2,1X,
```

```
     +                          A2,1X,A2,1X,A2,1X,A2)
                   Go to 120
              ENDIF
              GO TO 80

120      continue
         IF (numvar.LE.0) Go to 140
         do 130 s=1,numvar
             if((m(s).EQ.'E1').OR.(m(s).EQ.'E2').OR.


     +          (m(s).EQ.'E3')) then
             emiller=emiller+1
             endif
130      continue

140         varsmiller=varsmiller+numvar
            cumemiller=cumemiller+emiller
            cmiller=numvar-emiller
            chartmiller(cmiller,emiller)=chartmiller(cmiller,
     +                  emiller)+1


         do 150 t=1,18
            m(t)='  '
150      Continue

         m(num)=Model_var

         do 160 v=1,6
            Good_model(v)='  '
160      continue

         emiller=0
         numvar=0
         ModelNotFound=.TRUE.

70         continue

           write(12,*) ' '
           write(12,*) '*****************************************',
     +                 '*****************************************'
           write(12,*) ' '

           IF (varsmiller.GT.0) THEN
             avgvars = real(varsmiller)/60.0
             avgevars = real(cumemiller)/60.0
             millerpm = 1-(avgevars/avgvars)
           ELSE
             avgvars=0
             avgevars=0
             millerpm=0
```

```
      ENDIF

      write(12,*) 'The avg number of vars using Miller''s',
     +            ' method was ', avgvars
      write(12,*) 'The avg number of extraneous vars from',
     +            ' Miller''s method was', avgevars
      write(12,*) '****** The PM for Miller''s was ',
     +             millerpm,' ******'
      write(12,*) ' '
      write(12,*) '  '
      write(12,*) 'Correct Vars (0-3, down) -VS- ',


     +              'Extraneous Vars (0-3,across)'
      write(12,*) '  '
      write(12,*) ' Table for Miller''s Method'
      write(12,*) '  '
            do 170 w=0,3
                write(12,*) (chartmiller(w,x),x=0,3)

170           continue
      Write(13,*) n,'     ',millerpm

      do 180 y = 0,3
        do 190 z = 0,3
          chartmiller(y,z)=0
190     continue
180   continue

      varsmiller=0
      cumemiller=0

60    Continue
      Close(11)
      Close(12)
      Close(13)
      GO TO 1200

* Error trap: ******************************************

1000  Continue
      Print 1100, '+++ ERROR WHILE OPENING FILE +++',
     +            '      error code = ', IERROR
1100  FORMAT(/1X, A/ 1X, A, I8/)

*********************************************************

1200  CONTINUE
      Print *,'Counting complete.  ', NewOut,' written.'
      Go to 1300

90    Print*,'End of File encountered at line ',ReadCount
```

```
      Print*,'Design Point:',n,'  Replication:',p
      num=1
      Model_var='**'
      EndofFile=.TRUE.
      Go to 110

1300  CONTINUE
      END
```

Appendix M: SAS Programs

```
****************************** HLFMLR80.SAS ***********************

option linesize=80 pagesize=57;
filename new '           18.dat';
data dataset;
infile new ;
input set y x1 x2 x3 x4 e1 e2 e3;
data randset;
set dataset;
r1=RANNOR(0);
r2=RANNOR(0);
r3=RANNOR(0);
r4=RANNOR(0);
r5=RANNOR(0);
r6=RANNOR(0);
r7=RANNOR(0);
r8=RANNOR(0);
r9=RANNOR(0);
proc stepwise data=randset;
by set;
model y=x1 x2 x3 e1 e2 e3 r1 r2 r3 r4 r5 r6 r7 r8 r9 /forward
slentry=1;
filename new '           20.dat';
data dataset;
infile new ;
input set y x1 x2 x3 x4 e1 e2 e3;
data randset;
set dataset;
r1=RANNOR(0);
r2=RANNOR(0);
r3=RANNOR(0);
r4=RANNOR(0);
r5=RANNOR(0);
r6=RANNOR(0);
r7=RANNOR(0);
r8=RANNOR(0);
r9=RANNOR(0);
proc stepwise data=randset;
by set;
model y=x1 x2 x3 e1 e2 e3 r1 r2 r3 r4 r5 r6 r7 r8 r9 /forward
slentry=1;
                .                .
                .                .
                .                .

filename new '           64.dat';
data dataset;
infile new ;
input set y x1 x2 x3 x4 e1 e2 e3;
data randset;
```

```
set dataset;
r1=RANNOR(0);
```

```
********** INCP101.SAS **********
option linesize=80 pagesize=57 ;
filename new'            1.dat';
data dataset;
infile new;
input set y x1 x2 x3 x4 e1;
data randset;
set dataset;
r1=RANNOR(0);
r2=RANNOR(0);
r3=RANNOR(0);
proc stepwise data=randset ;
where set=          1;
model y=X1 X2 X3 r1 r2 r3 /forward slentry=1;

option linesize=80 pagesize=57 ;
filename new'            1.dat';
data dataset;
infile new;
input set y x1 x2 x3 x4 e1;
data randset;
set dataset;
r1=RANNOR(0);
r2=RANNOR(0);
r3=RANNOR(0);
proc stepwise data=randset ;
where set=          2;
model y=X1 X2 X3 r1 r2 r3 /forward slentry=1;

option linesize=80 pagesize=57 ;
filename new'            1.dat';
data dataset;
infile new;
input set y x1 x2 x3 x4 e1;
data randset;
set dataset;
r1=RANNOR(0);
r2=RANNOR(0);
r3=RANNOR(0);
proc stepwise data=randset ;
where set=          3;
model y=X2 X3 E1 r1 r2 r3 /forward slentry=1;

option linesize=80 pagesize=57 ;
filename new '            1.dat';
data dataset;
infile new;
input set y x1 x2 x3 x4 e1;
```

```
data randset;
set dataset;
r1=RANNOR(0);
proc stepwise data=randset ;
where set=          4;
model y=X3 r1 /forward slentry=1;
           .           .
           .           .
           .           .
option linesize=80 pagesize=57 ;
filename new'          63.dat';
data dataset;
infile new;
input set y x1 x2 x3 x4 e1;
data randset;
set dataset;
r1=RANNOR(0);
r2=RANNOR(0);
proc stepwise data=randset ;
where set=          60;
model y=X1 X3 r1 r2 /forward slentry=1;
```

```
********************* INVCP103.SAS ***********************

option linesize=80 pagesize=57 ;
filename new'            2.dat';
data dataset;
infile new;
input set y x1 x2 x3 x4 e1 e2 e3;
data randset;
set dataset;
r1=RANNOR(0);
r2=RANNOR(0);
proc stepwise data=randset ;
where set=          1;
model y=X1 X2 r1 r2 /forward slentry=1;

option linesize=80 pagesize=57 ;
filename new'            2.dat';
data dataset;
infile new;
input set y x1 x2 x3 x4 e1 e2 e3;
data randset;
set dataset;
r1=RANNOR(0);
r2=RANNOR(0);
r3=RANNOR(0);
r4=RANNOR(0);
proc stepwise data=randset ;
where set=          2;
model y=X2 X3 E1 E3 r1 r2 r3 r4 /forward slentry=1;

option linesize=80 pagesize=57 ;
filename new'            2.dat';
data dataset;
infile new;
input set y x1 x2 x3 x4 e1 e2 e3;
data randset;
set dataset;
r1=RANNOR(0);
r2=RANNOR(0);
proc stepwise data=randset ;
where set=          3;
model y=X3 E2 r1 r2 /forward slentry=1;

option linesize=80 pagesize=57 ;
filename new'            2.dat';
data dataset;
infile new;
input set y x1 x2 x3 x4 e1 e2 e3;
data randset;
```

```
set dataset;
r1=RANNOR(0);
r2=RANNOR(0);
proc stepwise data=randset ;
where set=           4;
model y=X2 X3 r1 r2 /forward slentry=1;
            .              .
            .              .
            .              .
option linesize=80 pagesize=57 ;
filename new'             64.dat';
data dataset;
infile new;
input set y x1 x2 x3 x4 e1 e2 e3;
data randset;
set dataset;
r1=RANNOR(0);
r2=RANNOR(0);
r3=RANNOR(0);
proc stepwise data=randset ;
where set=           60;
model y=X1 X3 E1 r1 r2 r3/forward slentry=1;
```

```
****************************** ONEMLR10.SAS ************************

option linesize=80 pagesize=57;
filename new '            1.dat';
data dataset;
infile new ;
input set y x1 x2 x3 x4 e1;
data randset;
set dataset;
r1=RANNOR(0);
r2=RANNOR(0);
r3=RANNOR(0);
r4=RANNOR(0);
proc stepwise data=randset;
by set;
model y=x1 x2 x3 e1 r1 r2 r3 r4 /forward slentry=1;
filename new '            3.dat';
data dataset;
infile new ;
input set y x1 x2 x3 x4 e1;
data randset;
set dataset;
r1=RANNOR(0);
r2=RANNOR(0);
r3=RANNOR(0);
r4=RANNOR(0);
proc stepwise data=randset;
by set;
model y=x1 x2 x3 e1 r1 r2 r3 r4 /forward slentry=1;
filename new '            5.dat';
data dataset;
infile new ;
input set y x1 x2 x3 x4 e1;
data randset;
set dataset;
r1=RANNOR(0);
r2=RANNOR(0);
r3=RANNOR(0);
r4=RANNOR(0);
proc stepwise data=randset;
by set;
model y=x1 x2 x3 e1 r1 r2 r3 r4 /forward slentry=1;

                .          .
                .          .
                .          .

filename new '            7.dat';
data dataset;
infile new ;
```

```
*****************************ONEMLR80.SAS*************************

option linesize=80 pagesize=57;
filename new '            2.dat';
data dataset;
infile new ;
input set y x1 x2 x3 x4 e1 e2 e3;
data randset;
set dataset;
r1=RANNOR(0);
r2=RANNOR(0);
r3=RANNOR(0);
r4=RANNOR(0);
r5=RANNOR(0);
r6=RANNOR(0);
proc stepwise data=randset;
by set;
model y=x1 x2 x3 e1 e2 e3 r1 r2 r3 r4 r5 r6 /forward slentry=1;
filename new '            4.dat';
data dataset;
infile new ;
input set y x1 x2 x3 x4 e1 e2 e3;
data randset;
set dataset;
r1=RANNOR(0);
r2=RANNOR(0);
r3=RANNOR(0);
r4=RANNOR(0);
r5=RANNOR(0);
r6=RANNOR(0);
proc stepwise data=randset;
by set;
model y=x1 x2 x3 e1 e2 e3 r1 r2 r3 r4 r5 r6 /forward slentry=1;

                  .             .
                  .             .
                  .             .

filename new '            6.dat';
data dataset;
infile new ;
input set y x1 x2 x3 x4 e1 e2 e3;
data randset;
set dataset;
r1=RANNOR(0);
r2=RANNOR(0);
r3=RANNOR(0);
r4=RANNOR(0);
r5=RANNOR(0);
r6=RANNOR(0);
```

```
****************************** LESSMLR.SAS ************************

option linesize=80 pagesize=57;
filename new '01.dat';
data dataset;
infile new ;
input set y x1 x2 x3 x4 e1;
data randset;
set dataset;
r1=RANNOR(0);
r2=RANNOR(0);
proc stepwise data=randset;
by set;
model y=x1 x2 x3 e1 r1 r2 /forward   slentry=1;
filename new '03.dat';
data dataset;
infile new ;
input set y x1 x2 x3 x4 e1;
data randset;
set dataset;
r1=RANNOR(0);
r2=RANNOR(0);
proc stepwise data=randset;
by set;
model y=x1 x2 x3 e1 r1 r2 /forward   slentry=1;
filename new '05.dat';
data dataset;
infile new ;
input set y x1 x2 x3 x4 e1;
data randset;
set dataset;
r1=RANNOR(0);
r2=RANNOR(0);
proc stepwise data=randset;
by set;
model y=x1 x2 x3 e1 r1 r2 /forward   slentry=1;

                .                .
                .                .
                .                .

filename new '07.dat';
data dataset;
infile new ;
input set y x1 x2 x3 x4 e1;
data randset;
set dataset;
r1=RANNOR(0);
r2=RANNOR(0);
proc stepwise data=randset;
```

```
****************************** SCRN1.SAS ************************

option linesize=80;
filename new '01.dat';
data new;
infile new ;
input z y x1 x2 x3 x4 e1;
proc rsquare data=new mse sp cp;
 where z= 1;
 model y=X1 X3        ;
proc rsquare data=new mse sp cp;
 where z= 2;
 model y=x4           ;
proc rsquare data=new mse sp cp;
 where z= 3;
 model y=X2           ;
proc rsquare data=new mse sp cp;
 where z= 4;
 model y=X3           ;
proc rsquare data=new mse sp cp;
 where z= 5;
 model y=X1 X3        ;
proc rsquare data=new mse sp cp;
 where z= 6;
 model y=X1 X3 E1     ;
proc rsquare data=new mse sp cp;
 where z= 7;
 model y=X2 X1 X3     ;
proc rsquare data=new mse sp cp;
 where z= 8;
 model y=X1 X3 X2     ;
proc rsquare data=new mse sp cp;
 where z= 9;
 model y=X2 X1        ;
proc rsquare data=new mse sp cp;
 where z=10;
 model y=X3           ;
proc rsquare data=new mse sp cp;
 where z=11;
 model y=X3           ;
proc rsquare data=new mse sp cp;
 where z=12;
 model y=X1 X2 X3     ;
proc rsquare data=new mse sp cp;
 where z=13;
 model y=X2 X1 X3     ;
proc rsquare data=new mse sp cp;
 where z=58;
 model y=X1 X2 X3     ;
```

```
proc rsquare data=new mse sp cp;
 where z=59;
 model y=X3          ;
proc rsquare data=new mse sp cp;
 where z=60;
 model y=X3          ;

         .      .
         .      .
         .      .

option linesize=80;
filename new '63.dat';
data new;
infile new ;
input z y x1 x2 x3 x4 e1;
proc rsquare data=new mse sp cp;
 where z= 1;
 model y=X1 X3 X2    ;
proc rsquare data=new mse sp cp;
 where z= 2;
 model y=X1 X3       ;
```

```
************************** SCRN11 ****************************
 option linesize=80;
 filename new '            2.dat';
 data new;
 infile new ;
 input z y x1 x2 x3 x4 e1 e2 e3;
 proc rsquare data=new mse sp cp;
  where z= 1;
  model y=x4           ;
 proc rsquare data=new mse sp cp;
  where z= 2;
  model y=x4           ;
 proc rsquare data=new mse sp cp;
  where z= 3;
  model y=X3 E2 X2     ;
 proc rsquare data=new mse sp cp;
  where z= 4;
  model y=X3 X2 X1     ;
 proc rsquare data=new mse sp cp;
  where z= 5;
  model y=X1 X3 E1     ;
.
.
.
  where z=57;
  model y=X3 X1 E1     ;
 proc rsquare data=new mse sp cp;
  where z=58;
  model y=X3 E3 X2     ;
 proc rsquare data=new mse sp cp;
  where z=59;
  model y=x4           ;
 proc rsquare data=new mse sp cp;
  where z=60;
  model y=X1 X2 X3     ;
 option linesize=80;
 filename new '            4.dat';
 data new;
 infile new ;
 input z y x1 x2 x3 x4 e1 e2 e3;
 proc rsquare data=new mse sp cp;
  where z= 1;
  model y=X2 X3 X1     ;
 proc rsquare data=new mse sp cp;
  where z= 2;
  model y=X2 X1 X3     ;
```

Bibliography

Bowerman, Bruce L. and O'Connel, Richard T. Linear Statistical Models An Applied Approach. Boston: PWS-KENT, 1990.

Drapper, N.R. and Smith, H. Applied Regression Analysis. New York: John Wiley & Sons, 1966.

Hansen, Capt Ross J. A Comparison of Variable Selection Criteria for Multiple Linear Regression: A Simulation Study. MS Thesis, AFIT/GOR/MA/88D-3. School of Engineering, Air Force Institute of Technology (AU), Wright-Patterson AFB OH, DEC 1988.

Hawkins, Clark A. and Weber Jean E. Statistical Analysis Application to Business and Economics. London: Harper & Row, 1980.

Hocking, R.R. "The Analysis and Selection of Variables in Linear Regression", Biometrics 32: 1-49 (March 1976).

Miller, Alan J. "Selection of Subsets of Regression Variables", Journal of Royal Statistical Society, Series A, 147, part 3: 389-425 (1984).

Miller, Alan J. Subset Selection in Regression. London: Chapman and Hall, 1990.

Mosteller, Frederick and Tukey, John W. Data Analysis and Regression. London: Addison-Wesley, 1977.

Neter, John and others Applied Linear Statistical Models. Boston: Irwin, 1990.

Woollard, Capt David P. A Comparison of Variable Selection Criteria for Multiple Linear Regression: A Second Simulation Study. MS Thesis, AFIT/GOR/ENS/93M-23. School of Engineering, Air Force Institute of Technology (AU), Wright-Patterson AFB OH, DEC 1993.

Vita

Lieutenant Ertem Mutlu was born 04 February 1965. In 1980 he entered Military High School in Istanbul. In 1984 he entered Turkish Air Force Academy and graduated in 1988 as a second Lieutenant with a Bachelor of Science degree, majoring in electronics. In 1989 he accomplished Basic Aircraft Maintenance Officer Training in Izmir and was assigned to Bandirma Air Force Base. In 1990, he was assigned to F-16 Aircraft Maintenance Training in Ft Worth Dallas. After working for a year in his previous base in 1992 he was assigned to the Air Force Institute of Technology.

He married former Nilgun Onder in 1988. They have a daughter Niler, 4 years old.

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